Performance Metrics
Results to Date

December 2001
Report

INTRODUCTION

This is the fourth semi-annual report on Free Flight Phase 1 (FFP1) performance metrics. The Free Flight Program Office established a metrics team and an initial set of performance metrics early in the FFP1 program, in collaboration with aviation stakeholders (represented by the RTCA Free Flight Steering Committee). The metrics team now includes research analysts, database specialists, and air traffic controllers from the following organizations: the FAA, MITRE Center for Advanced Aviation System Development (CAASD), The CNA Corp. (CNAC), TASC Inc., Seagull Technology, Analytics Associates, and the National Center of Excellence for Operations Research (NEXTOR). The purpose of the metrics is to establish accountability, provide near term feedback to implementation teams, and provide a basis for future free flight investments. This report focuses on performance analyses associated with the Center TRACON Automation System (CTAS), and updates previous analyses of the User Request Evaluation Tool (URET).

The primary FFP1 performance goals are to increase capacity (of both airports and airspace), reduce flight time and/or distance, and improve fuel efficiency, while maintaining system safety at current levels. For user benefits calculations, the metrics translate into delay savings after normalization for factors such as weather and demand.

An integral part of the metrics analysis involves in-depth discussions with air traffic controllers using the FFP1 tools. Because many factors influence daily traffic flows, our team focuses on specific areas where controllers have observed benefits from the tools. To assure a full understanding of how each new tool affects operational performance, results across all conditions are analyzed as well as "upstream" and "downstream" effects. For example, a metering tool such as TMA has no direct link to taxi times; however, we are interested in any significant ground movement changes linked to increased arrival rates. Other measures, such as tool usage, provide supporting evidence for the accuracy of the primary measurements.

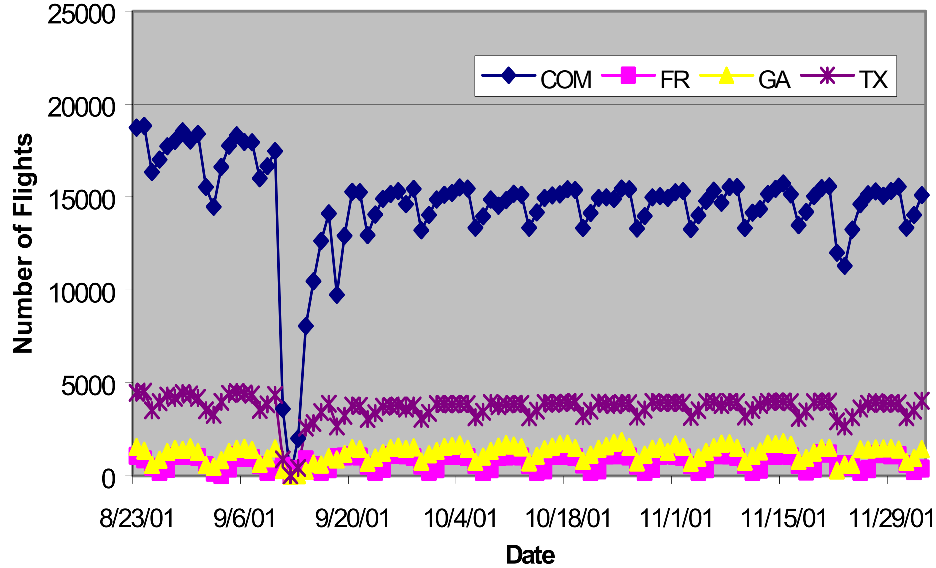
Although this document is not intended to forecast user benefits at sites where the tools have yet to be deployed, we have nevertheless attempted to show how the results at each site translate into user benefits.

In response to September 11th, we have included a special section following this introduction which highlights demand changes in the air traffic system. The FAA and the aviation community continue to recognize the need for additional capacity-enhancing tools. At the time of writing, demand already exceeds capacity at most major airports, and is continuing to increase to pre-September 11 levels. The FFP1 metrics focus on operational performance at peak periods when demand exceeds capacity. As shown in the pages to follow, FFP1 tools continue to provide benefits to NAS users.

If you have questions or comments on this document or the FFP1 metrics program please contact Dave Knorr at 202-220-3357 or Ed Meyer at 202-220-3407.

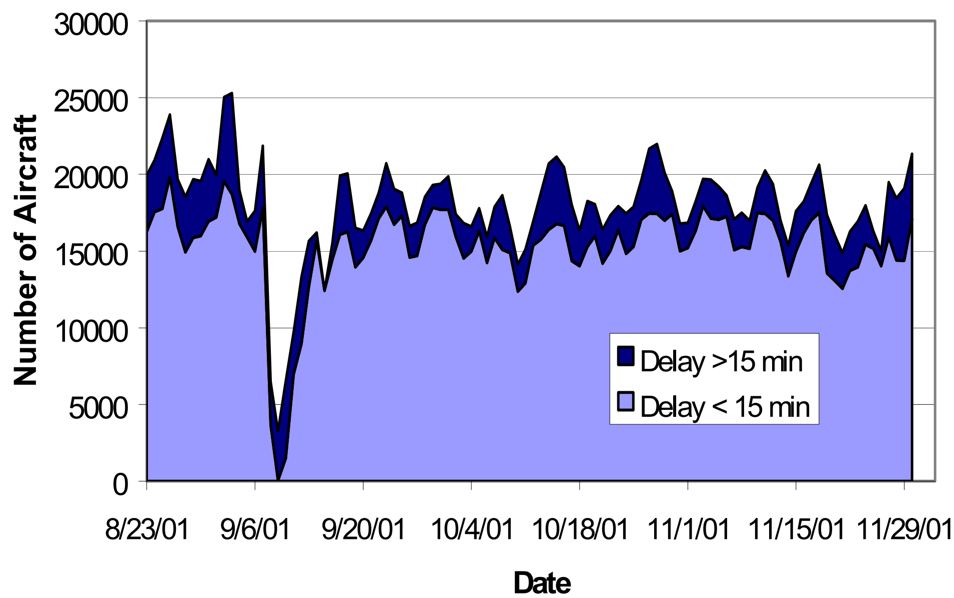
EFFECTS OF SEPTEMBER 11

September 11th has prompted changes in the air transportation system influencing the demand for air traffic control services as well as the mix of aircraft types being used. Figure i-1 shows National Airspace System (NAS) activity, by user category, before and after the September 11 tragedy. Figure i-2 illustrates the number of flights that were delayed more than 15 minutes relative to the total number of flights.



ETMS data, 8/23/2001 - 12/1/2001. User types: COM - Commercial, FR - Freight, GA - General Aviation, and TX - Air Taxi.

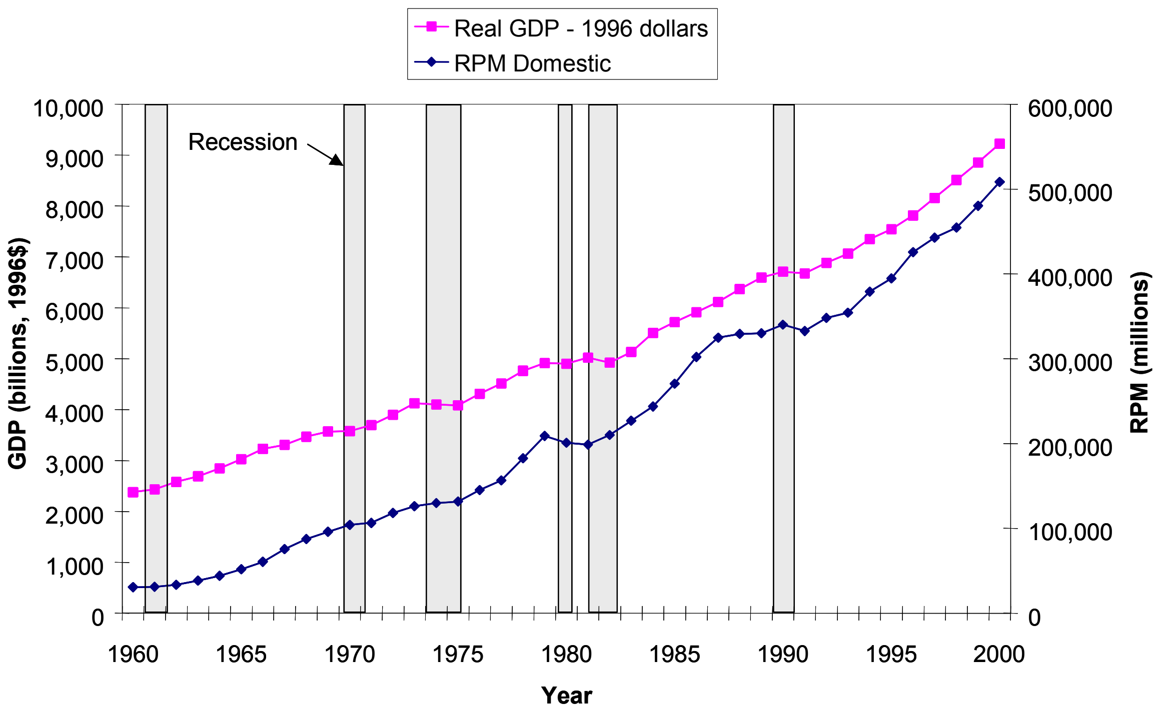
Figure i-1. Recent Flight History by User Type



ASPM data, 8/23/2001 – 11/30/2001. Delay < 15 minutes includes flights with no delay.

Figure i-2. Recent Flight History by Delay Amount

As new security measures are put into place, traffic and demand are on the rebound and the need for increased efficiency and capacity in the NAS remains a priority (Reference 1). While we do not know how long it will take for demand to reach pre-September 11 levels, one thing is certain: eventually those levels will be exceeded. As shown in Figure i-3, other dips in air traffic demand (as represented by revenue passenger miles) have been relatively short in duration. Events such as economic downturns, the controller strike, and the Gulf War caused these past dips. Since the recent terrorist attacks are unprecedented, the resumption of demand may take longer than following previous events. Also, the balance between the various types of system users may be forever changed.



RPM data from Air Transport Association, GDP data from Bureau of Economic Analysis, DOC, recession markings from Dow Jones (approximate).

Figure i-3. Gross Domestic Product and Airline Revenue Passenger Miles

Recent changes in demand and traffic mix tend to be site-specific. Figure i-4 shows that metering at Minneapolis/St. Paul International remains necessary; hence, demand levels frequently exceed capacity. Some of the metrics analyses and results described for CTAS do not include data past September 11th, even though a reduction of delay or of holding has been reported. At this time, we do not have sufficient data to normalize results for the changes since September 11. We have included anecdotal evidence, however, which supports the continued importance of CTAS in bringing improved service to NAS users.

The FAA and Free Flight Program Office maintain that there continues to be a strong need for investment in technologies which increase the capacity and efficiency of the NAS. Quantitative analyses of the value of these new capabilities will continue in order to gauge the effectiveness of past investments as well as to provide data for future decision-making.

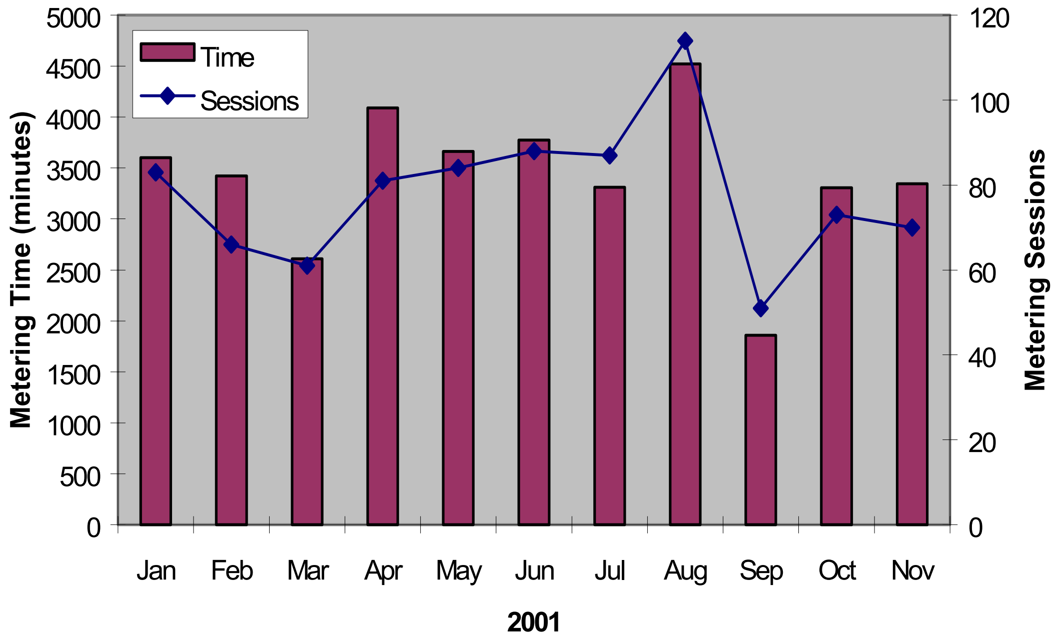


Figure i-4. CTAS Metering Time and Sessions at MSP

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1.0 SAFETY

1.1 Description

FFP1 capabilities are intended to provide benefits to users while maintaining the current high level of system safety. Safety has been the fundamental FAA objective since the agency was established, and it continues to underlie the development and implementation of every FFP1 tool. Safety objectives are reflected throughout the *Free Flight Phase 1 Program Master Plan* (Reference 2), the document that describes the implementation process for FFP1 capabilities.

To help meet these safety objectives, FFP1 management established a risk management process that tracks the performance of each FFP1 tool throughout the implementation phase. The FFP1 risk management team identified safety as one of two critical risk areas. To mitigate safety risks, service providers have been and will continue to be involved in both the design and validation of all FFP1 capabilities.

FFP1 safety metrics are being used to support the FFP1 safety evaluation, thereby helping to ensure that no fielded tool will inadvertently cause a reduction in system safety. As with all FFP1 metrics, the FFP1 safety metrics reflect collaboration with Stakeholders, and a consensus among airspace users, the FAA, industry, and unions.

In the FFP1 Metrics Plan, the principal safety metrics are defined to be the change in operational errors (OEs) and operational deviations (ODs) associated with the use of the FFP1 capabilities. The plan further states that, where possible, baseline data should be segregated by conditions or factors that influence the number of OEs and ODs (e.g., weather, traffic density, communications congestion). A recent enhancement to the use of OE and OD counts as safety metrics includes the recognition and tracking of the severity of such errors.

1.2 Metrics Used

The methodology being used by the FFP1 Metrics Team for the analysis of safety impacts can be summarized as follows:

- Track facility ODs and OEs during a baseline period and after implementation of FFP1 capabilities, focusing on the total number of errors/deviations per facility and the number of errors/deviations attributed to one or more FFP1 capabilities.

- In cooperation with the FAA Evaluations and Investigations Staff (AAT-20), analyze OE data in detail during the baseline and post-implementation periods to identify and track underlying factors. Examples of such factors include:

    - Traffic density

    - Controller readback errors

    - Communications problems

    - Inappropriate controller use of displayed data

- FFP1 capabilities in use.

- In coordination with FAA headquarters, regions and facilities, establish a process to collect pertinent information relating to OEs and ODs before and after FFP1 implementation. In particular, the Metrics Team will monitor the AAT-20 program to evaluate OEs and ODs as they occur. AAT-20 will advise the Metrics Team any time an FFP1 tool is identified as a factor in any OE or OD. In addition to tracking OE and OD counts, the Metrics Team will review data developed by AAT-20 on the severity of each operational error. This data - which has been developed and archived since April, 2001 – rates each OE on a severity scale from 1 to 100. The ratings reflect a set of specific characteristics for each OE, including miss distance, closure rate, relative flight paths and controller awareness/involvement.

- Track relevant data maintained by various FAA offices and other government agencies (e.g., NASA, NTSB), including:
  - Aviation Safety Reporting System (ASRS) data
  - NTSB Accident/Incident Reports
  - FAA Incident Data System
  - FAA Near Mid-Air Collision (NMAC) Database.

1.3 Analysis and Results

Analysts have long recognized that aviation safety is difficult to measure. Operational errors and deviations are commonly used as metrics, even though they are often the product of a complex series of events that make tracking causes and trends difficult.

In this analysis, the first step has been to track the number of OEs and ODs at each of the Free Flight Phase 1 sites. This data has been taken from the AAT-20 compilation of NAS-wide OEs and ODs. No significant change in monthly OE or OD rates beyond those experienced NAS-wide can be identified from these data.

Preliminary data on severity trends at FFP1 sites also show no identifiable trends to date.

Each OE and OD at an FFP1 site has also been evaluated to see if any FFP1 tool was identified as a factor. As of 1 December 2001, no FFP1 capability has been identified as a factor in any OE or OD. In addition, there have been no reports of the involvement of any FFP1 tool in the NTSB Accident/Incident Reports, the FAA Incident Data System, or the FAA NMAC Database as of 1 December 2001. To date, one NASA ASRS report has been submitted (DFW, December 2000) in which a pilot claimed “the computer” (presumably pFAST) assigned his aircraft to a runway that kept them high and fast on final approach. The pilot reported that he “barely made the [descent] parameters for a stabilized [approach].” No further negative consequences from this incident have been reported.

2.0 USER REQUEST EVALUATION TOOL (URET)

URET continues to produce user benefits in both Indianapolis (ZID) and Memphis (ZME) Air Route Traffic Control Centers (ARTCCs) through increased direct routings and reductions in static altitude restrictions. This section updates previous reports with analyses of distance savings from increased direct routings and fuel efficiency gains from fewer altitude restrictions.

URET Core Capability Limited Deployment (CCLD) is being deployed at the seven FFP1 Centers in the December 2001 through May 2002 timeframe. The system became operational at the Kansas City ARTCC on December 3 2001. The experience with the URET prototype at ZID and ZME provides confidence that similar benefits will accrue at the other FFP1 sites once the majority of controllers are suitably trained.

2.1 Description

The key URET capabilities for FFP1 include:

- Trajectory modeling,
- Aircraft and airspace conflict detection,
- Trial Planning to support conflict resolution of user or controller requests, and
- Electronic flight data management.

URET processes real-time flight plan and track data from the Host computer system. These data are combined with local airspace definitions, aircraft performance characteristics, and winds and temperatures from the National Weather Service in order to build four-dimensional flight profiles, or trajectories, for all flights within or inbound to the facility. URET also provides a "reconformance" function that continuously adapts each trajectory to the observed speed, climb rate, and descent rate of the modeled flight.

Once implemented, neighboring URET systems will exchange flight data, position, reconformance data, and status information in order to model accurate trajectories for all flights up to 20 minutes into the future.

URET maintains "current plan" trajectories (i.e., those that represent the current set of flight plans in the system) and uses them to continuously check for aircraft and airspace conflicts. When a conflict is detected, URET determines which sector to notify and displays an alert to that sector up to 20 minutes in advance. Trial planning allows a controller to check a desired flight plan amendment for potential conflicts before a clearance is issued. The controller can then send the trial plan to the Host as a flight plan amendment.

These capabilities are packaged behind a Computer Human Interface (CHI) that includes both textual and graphical information. The text-based Aircraft List helps the controller manage flight data electronically, reducing the dependence on paper flight strips. The Plans Display manages the presentation of current plans, trial plans, and conflict probe results for each sector. The Graphic Plan Display (GPD) provides a graphical capability to view aircraft routes and altitudes, predicted conflicts, and trial plan results. In addition, the point-and-click interface enables quick entry and evaluation of trial plan routes, altitudes, or speed changes, and enables the controller to send flight plan amendments to the Host.

For more details about URET capabilities, benefits, and the operational concept, please refer to Reference 3.[1]

2.2 URET at ZID/ZME

2.2.1 Operational Use

To date, analyses of URET's impact on operational performance are based on experiences at ZID and ZME. The functionality at these sites will be implemented at five additional Centers beginning in early 2002.

Figures 2-1 and 2-2 show the significant increases in flight plan amendments resulting in direct routings since July 1999, when the URET capability was extended to allow amendments to be sent directly to the Host Computer System (HCS). Direct routes are those that decrease distance, measured from the point of the amendment to the destination airport. Improving controllers' efficiency with URET results in increased benefits to users through more directs and a corresponding decrease in distance flown.

Particularly notable are the following:

- A slight decline in the total number of directs in September and October 2001. This is a result of the September 11th attacks, the resulting closing of airports, and a temporary decline in air traffic.

- A decline in the percentage of direct amendments entered via URET. In the spring of 2001 about 50 percent of the directs were entered via URET. In November 2001 URET accounted for about 36 percent of the directs at ZID and ZME. After the URET two-way HCS connection became operational in July 1999, controllers entered more direct amendments. Some of the directs previously had been given as clearances to pilots but not entered as amendments. URET made it much easier for controllers to enter directs. The HCS upgrade in the spring of 2001 also made it easier to enter these previously "voiced-only" clearances. The Free Flight Program Office (FFPO) maintains a goal of a 15 percent increase in the number of directs attributable to URET. The data still indicate an even larger increase.

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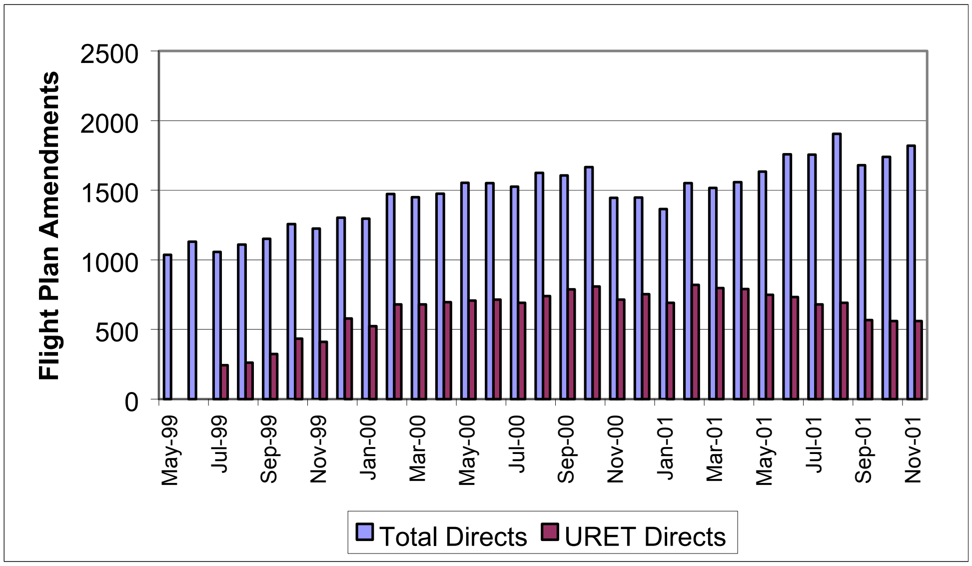
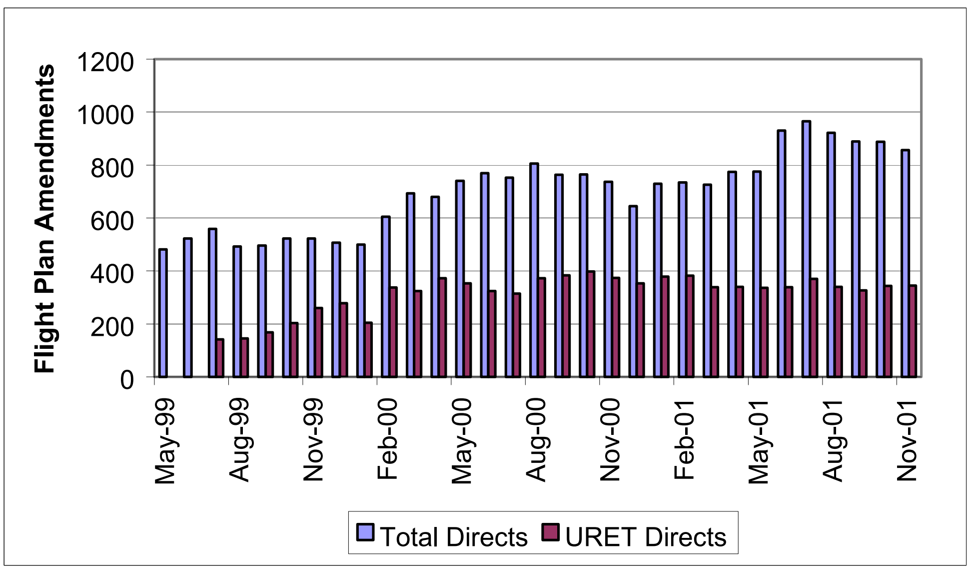
[1] The paper is available at the MITRE/CAASD Web site at http://www.mitrecaasd.org/library/tech_docs/1999/mp99w183.pdf.



Based on data collected on Wednesdays and Thursdays, 1300-2300 GMT.

Figure 2-1. URET Directs as a Subset of Total Directs: ZID



Based on data collected on Wednesdays and Thursdays, 1400-2200 GMT.

Figure 2-2. URET Directs as a Subset of Total Directs: ZME

2.2.1.1 Procedures

The increased URET usage at ZID and ZME has resulted in the establishment of new local procedures, captured in local orders and Memoranda of Understanding (MOUs). These procedures support the increased controller efficiency and consequent user benefits that URET enables. Some significant provisions of the local procedures are listed below:

- The Radar Associate Controller (RAC) has changed from "being a tactical position to that of a strategic planning position," [2] which provides the opportunity to resolve conflicts earlier, maneuvering aircraft less.
- The use of URET is mandated at all high and ultra-high sectors.[3]
- URET may be used in the developmental training of RACs.[4]
- During an extended 60 day test at ZME in 2000 and 2001, aircraft could fly at the wrong altitude for the direction of flight (WAFDOF) without standard coordination.[5]
- Under certain conditions, the sector team may suspend specific ZID intra-Center crossing restrictions when URET is operable.[6]
- The free text area shall be used for the following: Aircraft placed in hold; Estimated Departure Clearance Time (EDCT) of proposed flight plans for aircraft from non-Flight Data Input/Output (FDIO) airports; special handling requirements for aircraft; notification if flight data is not forwarded by the Host. This procedure supports a reduction in the use of paper strips; controllers use the free text area instead of strip marking.[7]

Many of these provisions of the local procedures are being incorporated in national procedures that will take effect after URET CCLD is deployed and a substantial number of controllers have received training. They reinforce the use of URET as a flight data management tool, and enable increased controller efficiency and better service to NAS users.

2.2.1.2 Procedures and Benefits Team

Both ZID and ZME established a Procedures and Benefits team to evaluate static altitude restrictions with the intent of eliminating them where feasible. The teams meet with industry pilots and airline representatives several times a year to collect user input. Static altitude restrictions are instituted at ARTCCs to help controllers manage incoming traffic and minimize voice coordination with upstream controllers. Controllers separate incoming aircraft from surrounding airspace to better manage the traffic flows. Static altitude restrictions are instituted both between sectors (as Standard Operating Procedures [SOPs]) and between Centers (as Letters of Agreement [LOAs]). Some crossing restrictions are airport related, e.g., Indianapolis arrivals shall cross from sector 87 to 88 at FL310. These restrictions specify the arrival or departure airport and the

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[2] ZME MOU between National Air Traffic Control Association (NATCA) and FAA, November 5, 1999.

[3] Ibid.

[4] ZME Order 6100.2D, effective February 9, 2001.

[5] ZME waiver to Order 7110.65.

[6] ZID Order 7800.1A, effective November 1, 2000.

[7] Ibid.

sectors or Centers to which they apply. Static altitude restrictions constrain aircraft to lower altitudes than might otherwise be desired. URET enables ARTCCs to eliminate many of these static altitude restrictions. Controllers rely on the advance information provided by URET to separate incoming aircraft from each other, rather than separating the aircraft from airspace reserved for a separate traffic flow. Aircraft may therefore stay at their preferred altitudes longer, reducing fuel burn and saving users money.

2.2.2 Metrics Used

The primary metrics that address benefits to NAS users are distance/time saved, static altitude restrictions lifted, and increased airspace capacity. The metrics on distance saved and reduction in static altitude restrictions update the data in the FFP1 June 2001 report (Reference 4). Please refer to the June 2001 report for a more complete description of the metrics.

Several measures were employed to estimate the distance savings facilitated by URET. These measures include:

- Change in miles flown because of lateral amendments
- Change in average distance flown through each Center's airspace
- Change in distance flown for specific city pairs.

In addition to distance savings, there have been improvements in fuel efficiency resulting from the removal of altitude restrictions. The ZID Procedure and Benefit team was established to evaluate and modify or remove altitude restrictions. While now temporarily suspended, the team will resume their work after the deployment of URET CCLD. Once URET is deployed to all bordering Centers, ZID will have increased opportunity eliminate interfacility restrictions.

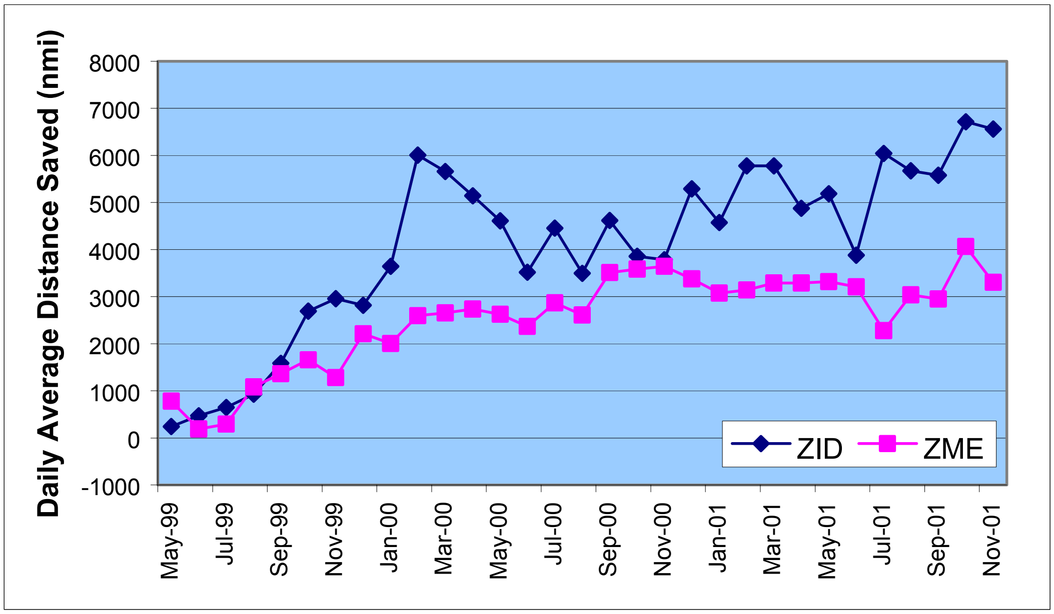
2.2.3 Analysis and Results

This section presents the results of analyses at ZID and ZME of reduction in miles flown and static altitude restrictions lifted. The primary measure used for the reduction in miles flown is based on data captured directly from URET. We examined all lateral flight plan amendments entered into the Host, and computed the distance savings. Two other metrics, *Excess Distance in Center* and *Savings by City Pairs in En Route Airspace*, support the results derived from the analysis of lateral amendments and are discussed later in this section. The analysis of user savings from the elimination of static altitude restrictions is based on fuel burn data provided by airlines.

2.2.3.1 Lateral Amendments

Lateral amendments are defined as those that change the direction of an aircraft but not necessarily its altitude. They include penalties (e.g., turns to avoid congested or heavy weather areas) as well as savings in distance. The distance saved metric captures the average of the daily sum of distance changes resulting from lateral amendments. Distance saved is computed from the point of the amendment to the destination airport.

The data include all lateral amendments entered into the Host for the specified time, not only URET amendments. The "savings" have increased from approximately 500 nmi daily (May and June 1999, before URET could send amendments to the Host) to over 4,300 nmi through August 2001. The October 2001 average is almost 5,400 nmi, but the September/October metrics are impacted by the September 11th terrorist attacks; there were fewer aircraft flying, less congestion, and longer directs.



Based on data collected on Wednesdays and Thursdays, 1400-2200 GMT at ZME, 1300-2300 GMT at ZID.

Figure 2-3. Distance Saved from Lateral Ammendments

The cost savings accruing to users from these distance savings were estimated using data provided by the Air Transport Association (ATA). We assume an average ground speed of 7 miles per minute. ATA's preliminary delay cost estimate for 2000 is $62.50 per airborne minute. When ZID and ZME are averaged together, and using the August figures, the distance saved over the baseline is about 3,800 nmi per Center (the baseline is defined as prior to the URET two-way Host interface), or about 550 minutes per Center. At $62.50 per minute, the savings per month is about $1,032,500 per Center, or $2,065,000 for both Centers. We believe that this savings estimate is conservative because distance saved has only been estimated for the 10 busiest hours of the day.

2.2.3.2 Excess Distance and En Route Distance between Selected City Pairs

This section discusses two other metrics which support the lateral distance savings discussed above: excess distance within a Center (actual distance flown minus the great circle distance), and savings in total en route distance (not only ZID and ZME) between selected city pairs.

2.2.3.2.1 Excess Distance

Excess distance is the difference between the actual distance flown and the great circle distance from the Center entry to exit points. For simplicity, we assume that the great circle route is the most efficient route of flight. The smaller the excess distance, the more efficient the flight. Figure 2-4 compares the excess distance per aircraft at ZID and ZME with the other URET CCLD Centers. Data are being collected at the new URET Centers in order to establish a baseline against which performance with URET may be gauged. The excess distance flown metric is calculated for all days of the month. The metric shows a slight increase from January 2000 through August 2001 for both ZID and ZME.

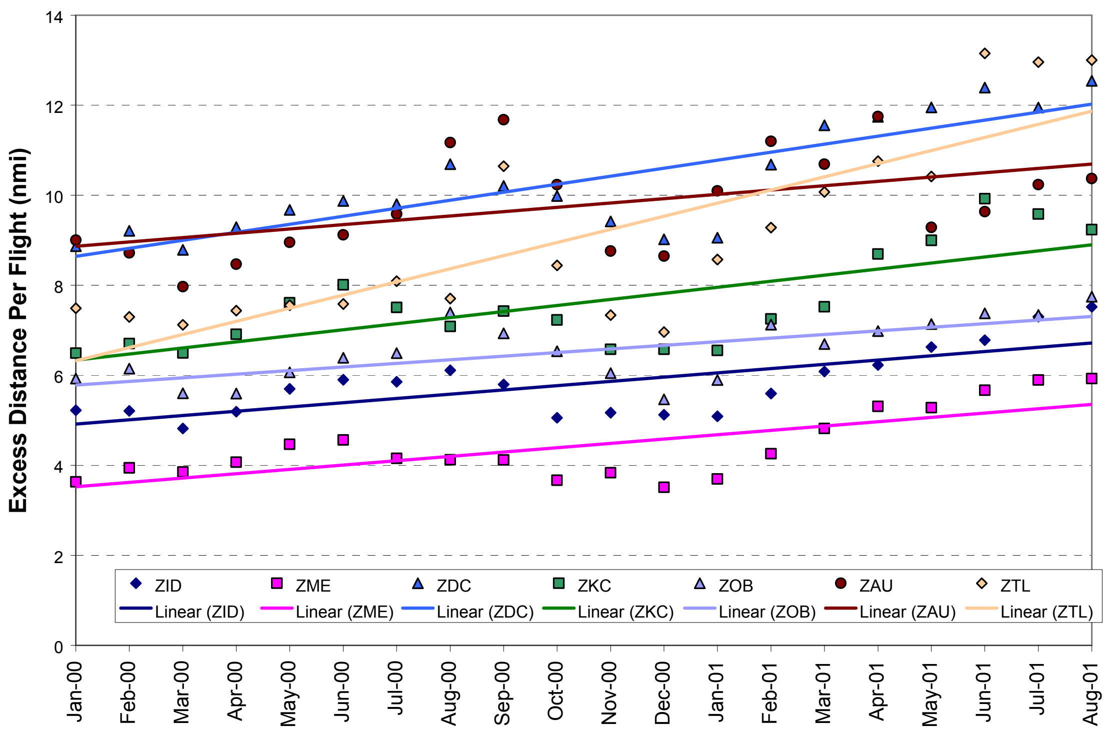


Figure 2-4. Excess Distance Trends at URET CCLD Sites

ZID and ZME had the least excess distance of any of the seven URET CCLD Centers. The difference between ZID and ZDC is particularly notable. ZDC has about the same traffic as ZID (see Table 2-1) and about 80 percent more airspace. The excess distance for ZDC (almost 12.5 nmi in August 2001) and the upward slope (from approximately 9 to 12.5 nmi) is not accounted for by either quantity of airspace or quantity of traffic. Traffic complexity and route structure may significantly affect aircraft routing. The impact of URET will be monitored over time at all the sites.

Table 2-1. Airspace and Traffic Comparison: ZID, ZME, and ZDC

Center	Geographic Area (sq. nmi)	2000 Traffic (IFR Operations)*	Airspace Relation to ZID	Traffic Relation to ZID
ZID	73,000	2,685,000	-	-
ZME	116,000	2,232,000	Approx. 60% more	Approx. 17% less
ZDC	130,000	2,772,000	Approx. 80% more	Slightly more

*Source: FAA Administrator's Fact Book, April 2001.

2.2.3.2.2 En Route Distance

The En Route Distance metric takes a broader look at the impact of URET on flights that *traverse* ZID or ZME airspace. One question of interest is whether a flight distance savings realized in ZID or ZME would be offset or reduced by an increase in flight distances in other ARTCCs. Unlike the previous metrics, which examine the impact of URET within ZID or ZME, this analysis explores the distance savings question by looking at the entire "en route" portion of a flight.

To answer this question, the en route distance was calculated for flights traversing ZID or ZME airspace over a 2-year period (May 1999 to August 2001). For details on how en route distance was calculated see Reference 4. The results are illustrated in Figures 2-5 and 2-6. The en route trends indicate slight decreases in distance between city pairs for both Centers, but these are statistically insignificant.

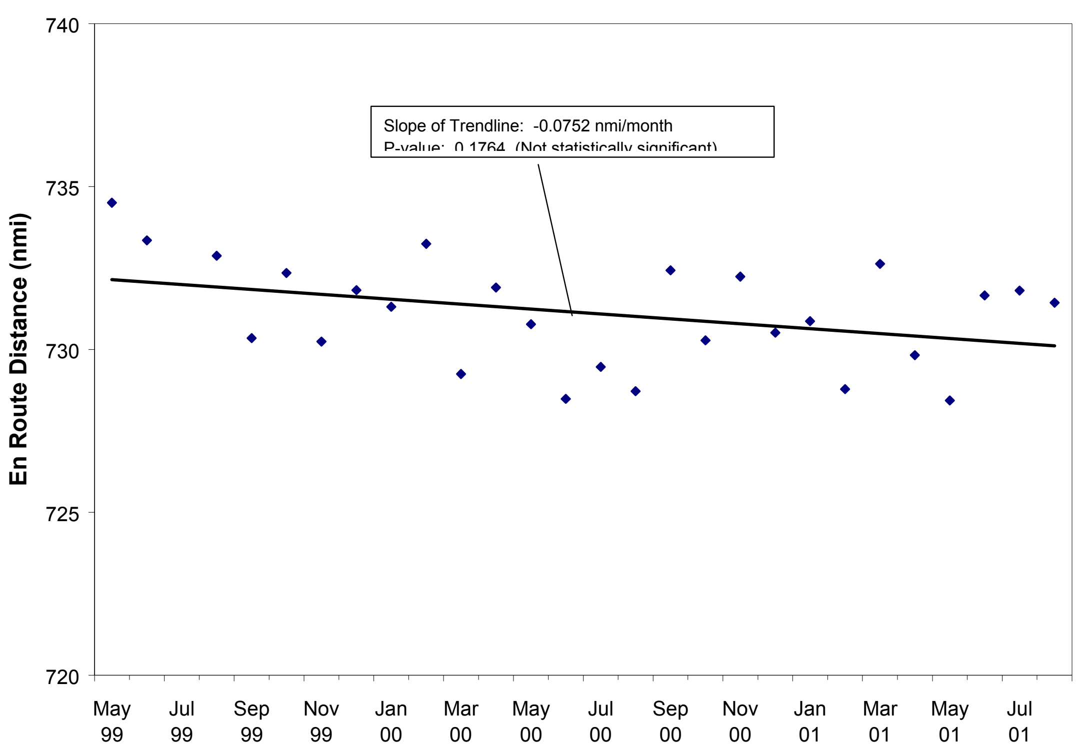


Figure 2-5. En Route Distance Trend: ZME

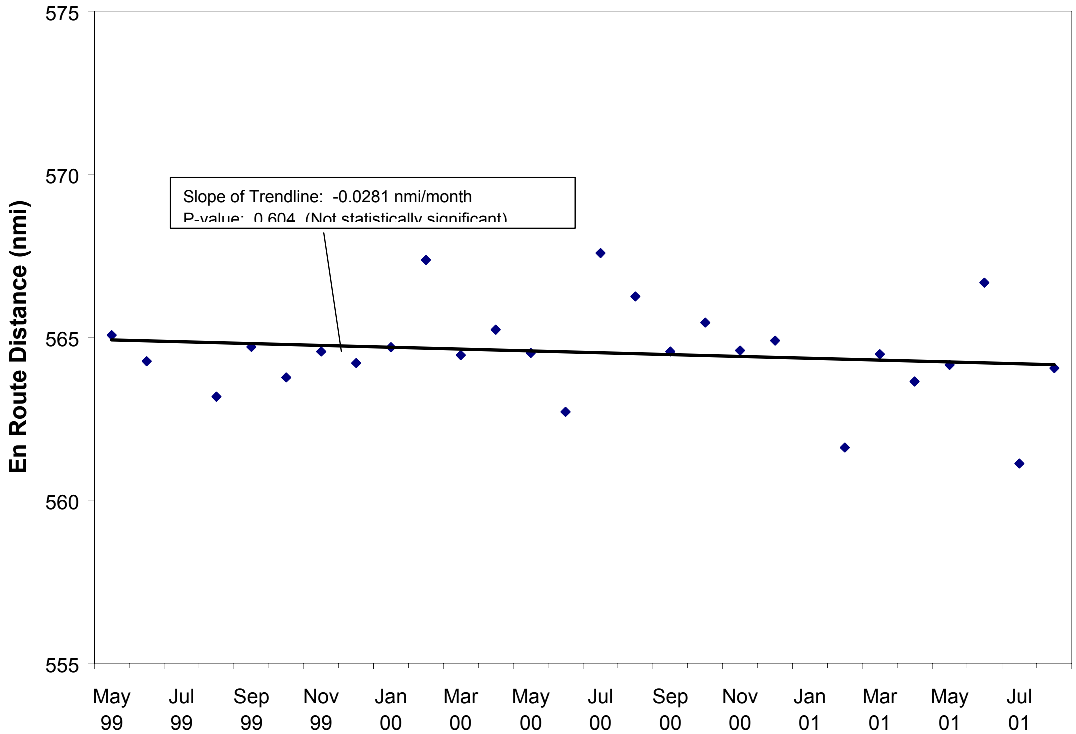


Figure 2-6. En Route Distance Trend: ZID

2.2.3.3 Lifting of Static Altitude Restrictions

The Procedure and Benefit team at ZID is now part of the core cadre preparing for deployment of URET CCLD. Their work in evaluation of static altitude restrictions for modification or removal has been temporarily suspended and will resume after URET CCLD is deployed. The benefits accruing to NAS users to date are listed in Table 2-2. For details on the methodology used in the lifting of static altitude restrictions, see Reference 5.

Table 2-2. History of Static Altitude Restriction Removal: ZID

Restrictions Lifted or Modified	Estimated Annual Fuel Savings
Apr. – Nov. 2000 – 6 restrictions	234,350 Gallons
Mar. – Apr. 2001 – 13 restrictions	770,885 Gallons
Possibly Lift fall 2001 – 1 restriction	23,716 Gallons (not included in total)
Estimated Annual Savings	**935,235 Gallons**

3.0 CENTER-TRACON AUTOMATION SYSTEM (CTAS)

The Center-TRACON Automation System (CTAS) consists of two major components. Traffic Management Advisor (TMA) is currently operational at Ft. Worth, Minneapolis, Denver, Los Angeles, Atlanta, Miami, and Oakland ARTCCs. Activity on the TRACON component of CTAS, the Passive Final Approach Spacing Tool (pFAST), was terminated as a result of the tool's inability to function adequately in dynamic situations. An alternative component, CTAS-Terminal, was developed and is in use at the Southern California TRACON (SCT). This section describes the operational use of these tools at the FFP1 sites, outlines the analyses used in measuring benefits, and presents some results.

3.1 Description

TMA assists controllers in the enroute cruise and transition airspace around major airports by providing them with a means of optimizing arrival throughput. By optimizing throughput, TMA helps to reduce arrival delays. The resulting uniformity of arrival flows can also lead to an increase in departure rates and a decrease in departure delays. Inputs to the TMA system include real-time radar track data, flight plan data, and a three-dimensional grid of wind speeds and directions. TMA's trajectory models use this information, updated every 12 seconds, to compute routes and optimal schedules to the TRACON meter fixes for all arriving IFR aircraft, with consideration given to separation, airspace, and airport constraints.

TMA was initially implemented at Ft. Worth Center before the establishment of the Free Flight Phase 1 program, concurrent with the redesign of Dallas/Ft. Worth terminal airspace, so no applicable baseline data is available for this site. The impact of TMA at Dallas/Ft. Worth was analyzed by the NASA Ames Research Center (Reference 6), and was discussed in the June 2000 metrics report (Reference 5). No further analysis of this site is envisioned. This report updates the analysis of TMA at Minneapolis and Denver Centers that was formerly presented in the June 2001 report (Reference 4), and introduces a discussion of TMA at Los Angeles, Atlanta, Miami, and Oakland Centers.

The terminal component of CTAS assists controllers and air traffic managers in managing the arrival flow in terminal airspace. It provides a bigger picture of the overall flow to a controller, allowing for greater situational awareness. This report updates the initial analysis of CTAS-Terminal at SCT from the June 2001 report.

3.2 TMA at ZMP/MSP

3.2.1 Operational Use

At Minneapolis Center (ZMP), TMA is used both as a strategic planning tool by the Traffic Management Unit (TMU) and tactically by controllers who are actively controlling aircraft. Initial Daily Use (IDU) of TMA at ZMP for Minneapolis International Airport (MSP) began in June 2000. The TMA computer interface incorporates two primary strategic displays. The Timeline Graphical User Interface (T-

GUI) displays estimated time of arrival, CTAS-computed delay, scheduled time of arrival, and runway assignment for each track in the TMA area of regard. The Planview Graphical User Interface (P-GUI) displays aircraft arriving at an airport in two-dimensions from above. TMU managers use these and other displays to determine if and when time-based metering needs to be imposed in the Center's airspace so that the arrival rate specified by the Minneapolis TRACON (MSP) is not exceeded. When metering is imposed, floor controllers see a sequence list overlaid on their radar displays that indicates which aircraft need to be delayed and by how much.

Figure 3-1 presents TMA metering times for MSP. Although the total metering times vary substantially by month, the overall trend of the dataset from August 2000 to August 2001 suggests that the total monthly metering times at MSP have gradually increased. Although the amount of metering fell in September 2001 (presumably due to decreased demand after September 11th), the amount of metering in October 2001 is similar to the amount in July 2001 and is much larger than October 2000.

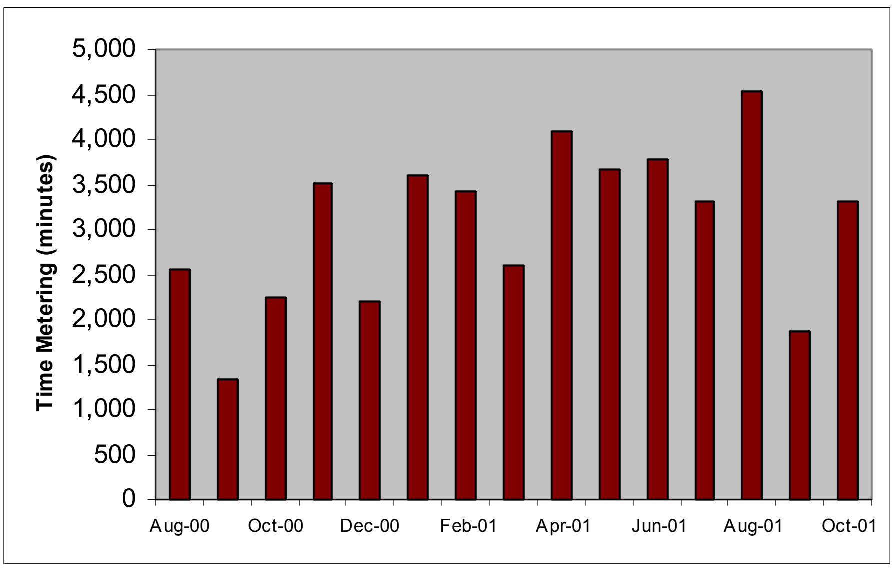


Figure 3-1. ZMP/MSP Total Monthly Metering Times

3.2.2 Metrics Used

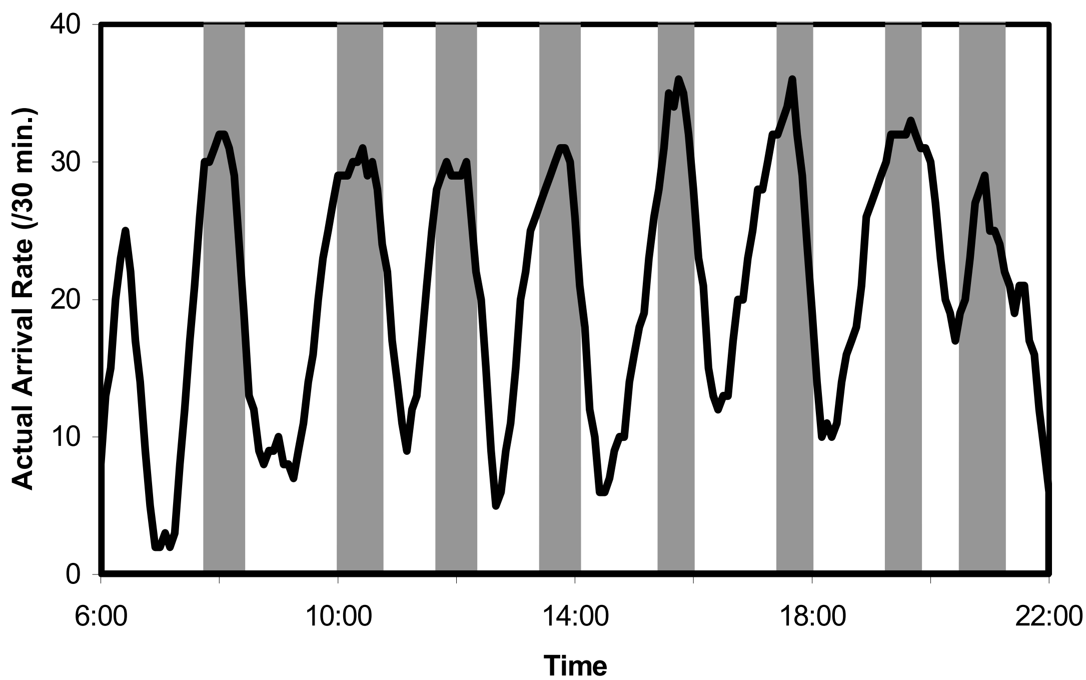
The TMA evaluation at each of the FFP1 Core Capability Limited Deployment (CCLD) sites focuses on safety, capacity improvement, and efficiency of user operations. Safety has already been discussed in Section 1.0 of this report. FFP1 capacity metrics for TMA seek to address the following issue: *Does TMA increase peak-period throughput at airports where it is implemented?* We anticipate that by smoothing the flow of arriving traffic during arrival peaks TMA metering will help TRACON controllers to land more airplanes in a given period. Thus our primary TMA capacity metrics are:

- Airport Acceptance Rate (AAR)
- Actual peak-period arrival rate.

It is also possible that by making arrival flows more predictable, TMA will help TRACON and tower controllers depart more aircraft during arrival peaks. This is especially true at MSP where arrivals and departures frequently share runways. For MSP we also include the capacity metric of:

- Actual peak-period operations rate (arrivals plus departures)

Much of the analysis mentioned above relies on determining peak arrival periods at MSP. Figure 3-2 illustrates a typical day at MSP. There are six distinct arrival peaks resulting from Northwest Airlines hub scheduling practices, and one or two somewhat less distinct peaks between 19:30 and 20:30 local time. We use an algorithm to isolate peaks from arrival data of the type illustrated in Figure 3-2. This algorithm identifies the closest-spaced 30 aircraft during periods of at least 30 minutes when the arrival rate is greater than the day's average arrival rate. These 30 aircraft typically land within a 28 minute period. We then compute an equivalent hourly arrival rate for this period of time. The hourly arrival rate, or "Peak 30 Rate," then becomes one observation for subsequent statistical analyses.



Shading indicates peak periods.

Figure 3-2. Example of Arrival Peaks at MSP

Efficiency metrics for TMA seek to address the following issues:

- *Does TMA impact flight times for traffic arriving at airports where it is implemented?*
- *Does TMA redistribute delay from lower to higher, more fuel efficient altitudes for arriving aircraft at airports where it is implemented?*

By helping ARTCC controllers to meter arriving traffic, TMA may reduce the flight time for those flights by reducing holding or vectoring outside of TRACON airspace. On the other hand, it is possible that arrival rates to the TRACON are increased, but that landing rates cannot be increased, so that final approach segments need to be increased and additional delays are obtained within the TRACON. The TMA efficiency metrics therefore attempt to determine whether overall flight time from the point where TMA first detects an arriving aircraft (200 nm from the arrival airport or at the Center boundary, whichever is closer) to the runway threshold have changed.

Use of TMA might also redistribute delay from the lower altitudes of the TRACON to the higher altitudes of Center airspace. This would be advantageous to aircraft operators, since aircraft typically burn less fuel per unit of time when flying fast at high altitudes than when "low and slow." Thus, even with no change in total delay, any redistribution of delay between the TRACON and Center should be measured.

For this analysis the TMA efficiency metrics are:

- Flight time and distance from the 160 nmi ring to the runway threshold
- Fraction of flight time and distance from the 160 nmi ring to the threshold that is within TRACON airspace.

3.2.3 Analysis and Results

We can detect no statistically significant change in acceptance rates at MSP since TMA adoption at Minneapolis Center. However, we have measured an increase in acceptance rate of one aircraft per hour during instrument conditions since the TMA displays became operational at the TRACON. We have also detected an *increase* in actual arrival rates of about one arrival per hour during peak periods. We believe that this increase in arrival rates results from the smoother flow of traffic being delivered to the TRACON with TMA.

The peak operations rate (the sum of the arrival rate and departure rate) has also *increased* by about four operations per hour. We suspect that the smoother arrival flows at MSP during peak periods have allowed tower and TRACON controllers to depart more aircraft during these periods. There has been a *decrease* in flying distances in the extended terminal area (defined here as 160 nmi from the airport to the runway) of from five to nine nautical miles for arriving flights during arrival peaks. There has also been a small shift in flight distance from terminal to more fuel efficient Center airspace.

In summary, we have thus far observed the following at MSP:

- an increase in AAR during instrument approaches following TMA deployment to the TRACON
- an increase in actual arrival rates and operations rates during arrival peaks
- a decrease in flight distance (or an increase in efficiency) for peak-period arrivals
- a shift in delay from terminal airspace to Center airspace.

3.2.3.1 Airport Acceptance Rate

When examining the impact of a change in automation or procedures at an ATC facility, we typically begin by examining the rates that the facility is specifying to see if any change has occurred; for TMA at MSP, this means the Airport Acceptance Rate (AAR). We examined AARs at MSP from 1 October 1999 through 31 October 2001 in order to see if the TRACON has increased rates since TMA was implemented.[8] TMA became operational at ZMP/MSP in late June 2000, but we have elected to exclude data from 15 June 2000 to 15 July 2000 from this (and all subsequent) analyses because of uncertainties concerning the status of the system during that time period. We have also excluded data from September 2001 because of the sharp decrease in demand immediately following September 11th. The data for these analyses were obtained from facility logs, which were reviewed each day. AAR changes were entered in the FFP1 operational performance database.

We first conducted a simple Analysis of Variance (ANOVA) on the AAR log entries, weighted by the length of time for which each entry was in effect. We used two factors in this analysis: a TMA factor, representing the use of TMA (which commenced in the summer of 2000); and an IFR factor, indicating when instrument approaches were in use. The interaction between these two factors was also included. We found no detectable change in AAR following TMA introduction using this methodology (the same result that we reported earlier in Reference 4).

We then took another look at the potential change in AAR at MSP, focusing on the introduction of TMA displays into the TRACON. Typically, when TMA is implemented in an ARTCC, display repeaters are also installed at the associated TRACON. These displays provide TRACON traffic managers with improved knowledge of the traffic that will shortly be entering their airspace. Traffic managers at the DFW TRACON reported that this improved knowledge allowed them to increase arrival rates for their airport by five percent. Because of a renovation of the MSP TRACON, the TMA displays were not available until July 2001. We repeated the ANOVA described above, but this time compared the base case (pre-TMA) to the period starting on 18 July 2001, when TMA was fully operational at the ARTCC *and* TMA displays were operational at the TRACON. Again, the data for September 2001 were not included in this analysis. The results of this ANOVA indicate a significant interaction between the TMA and IFR factors. Because of this, we elected to conduct a linear regression of the impact of these factors on the AAR.

Table 3-1 presents the AAR regression results. The regression indicates that TMA has not had an impact on AAR by itself, but that it has when coupled with the instrument approaches variable (IFR). On average, the AAR is about one arrival per hour greater during instrument approaches following the introduction of TMA to the ARTCC and the TRACON. This result is statistically significant at the five percent level. There still appears to be no change in AAR for visual approach conditions.

---

[8] While we have data prior to 1 October 1999, there was taxiway construction activity at the airport prior to this date. Consequently AARs were lower at that time.

Table 3-1. MSP Acceptance Rate Regression

Dependent Variable: AAR weighted by minutes in configuration

R Square	Adjusted R Square	F	Sig.
.227	.226	165.049	.000

Parameter	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	59.156	.148		401.046	.000
TMA	.458	.268	.043	1.706	.088
IFR	-5.187	.265	-.493	-19.584	.000
TMA * IFR	1.008	.504	.057	2.000	.046

Parameter	Description
TMA	0 = pre-TMA introduction at ZMP, 1 = post-TMA introduction at ZMP & MSP
IFR	0 = visual approaches, 1 = instrument approaches

3.2.3.2 Actual peak-period arrival rate

Figure 3-4 presents the mean peak arrival rates before and after TMA implementation at ZMP, for both visual and instrument approaches. The same time period used for the analysis of acceptance rates was also used here, namely 1 October 1999 through 31 October 2001 (without September 2001), providing 5,529 observations. This simple comparison of means suggests that peak arrival rates are slightly higher since TMA introduction, with a somewhat larger increase when instrument approaches are being conducted. As expected, arrival rates overall are lower under instrument approach conditions.

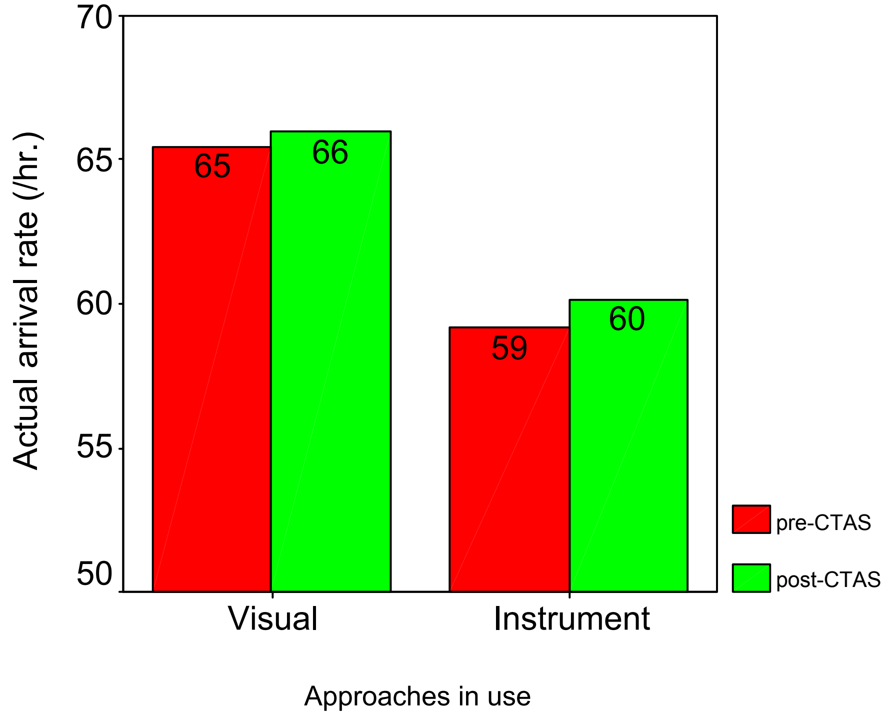


Figure 3-4. MSP Mean Actual Arrival Rate

3.2.3.3 Actual peak-period operations rate

We also examined the potential impact of TMA on total operations at MSP during arrival peaks. It has been suggested that the use of TMA smoothes the arrival flow to such an extent that the tower is able to increase the number of departures during arrival rushes (arrivals and departures share the same runways at MSP). In order to test this, we summed the arrival rate examined above with the departure rate achieved at the same time to obtain an operations rate.

Figure 3-5 presents the mean peak-period operations rates at MSP from 1 October 1999 through 31 October 2001 (without September data). There appears to be a significant increase in the operations rate under both visual and instrument conditions. If we separate the October 2001 data and compare it with the pre-TMA data, we still find an increase in operations (see Figure 3-6), albeit smaller than the average increase over the entire post-TMA time period.

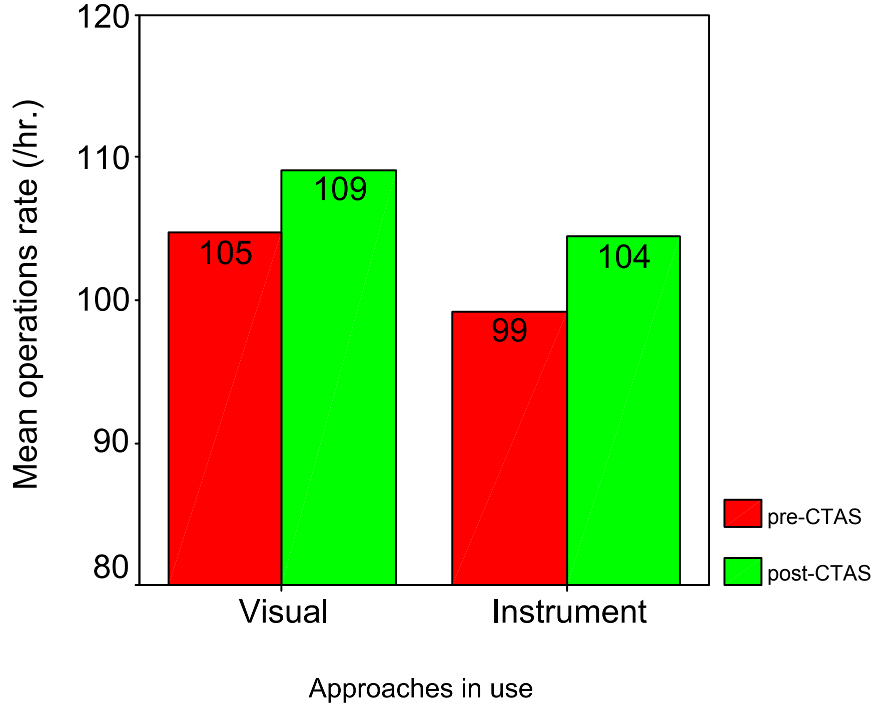


Figure 3-5. MSP Mean Operations Rate, October 1999 – October 2001

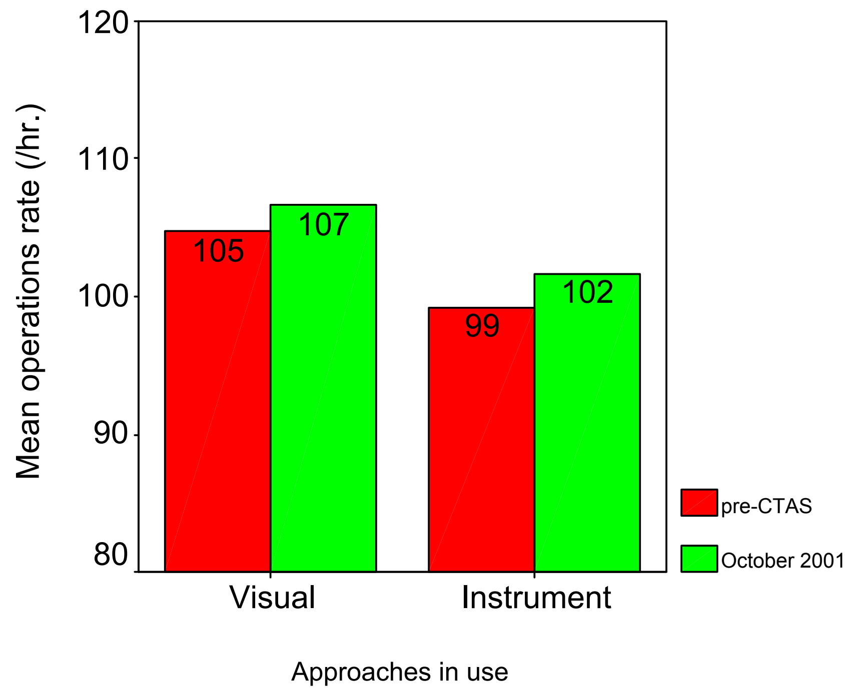


Figure 3-6. MSP Mean Operations Rate, pre-CTAS vs. October 2001

3.2.3.4 Flight Times and Distances

As part of the analysis of the effects of TMA at MSP we analyzed arrival aircraft flight times and distances in Minneapolis Center (ZMP) airspace. TMA uses the AAR called by the TRACON to meter aircraft. If issuing delay to the arriving aircraft is necessary, it is most economical to incur delay (i.e., speed control or vectoring) at higher altitudes where aircraft are more fuel efficient.

To conduct our analyses, we divided the Center airspace through which arriving aircraft must fly into segments associated with a set of imaginary arcs centered at MSP (see Figure 3-7). The predefined arcs are as follows: Extreme Arc (EA) at 200 nmi, Outer Arc (OA) at 160 nmi, Inner Arc (IA) at 100 nmi, and Meter Arc (MA) at 40 nmi. Host data was used to calculate the average flying time and distance across each of these arcs for those flights that arrived at MSP.

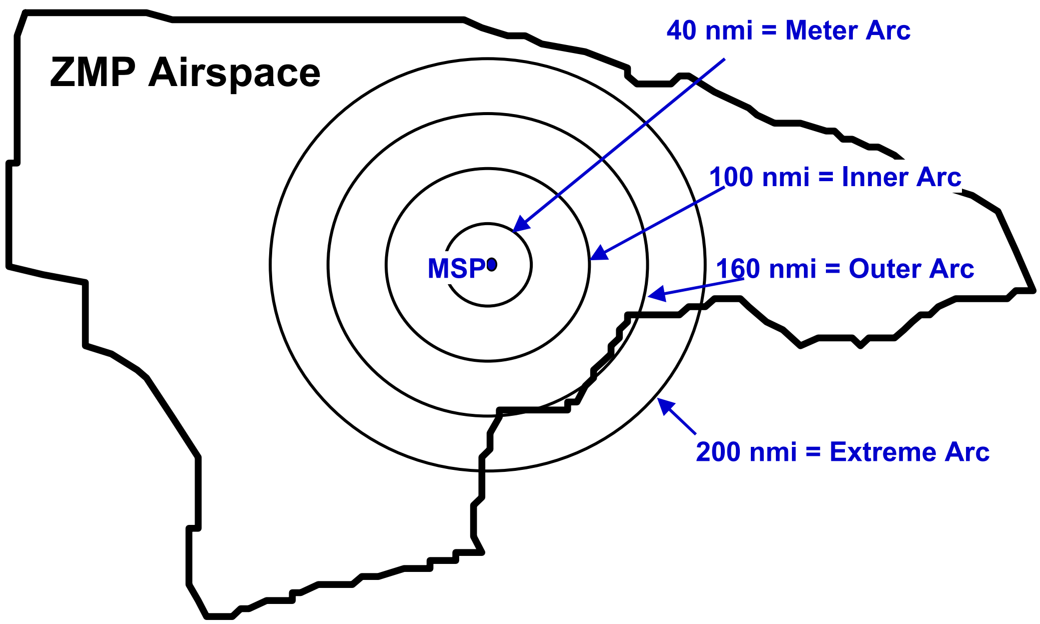
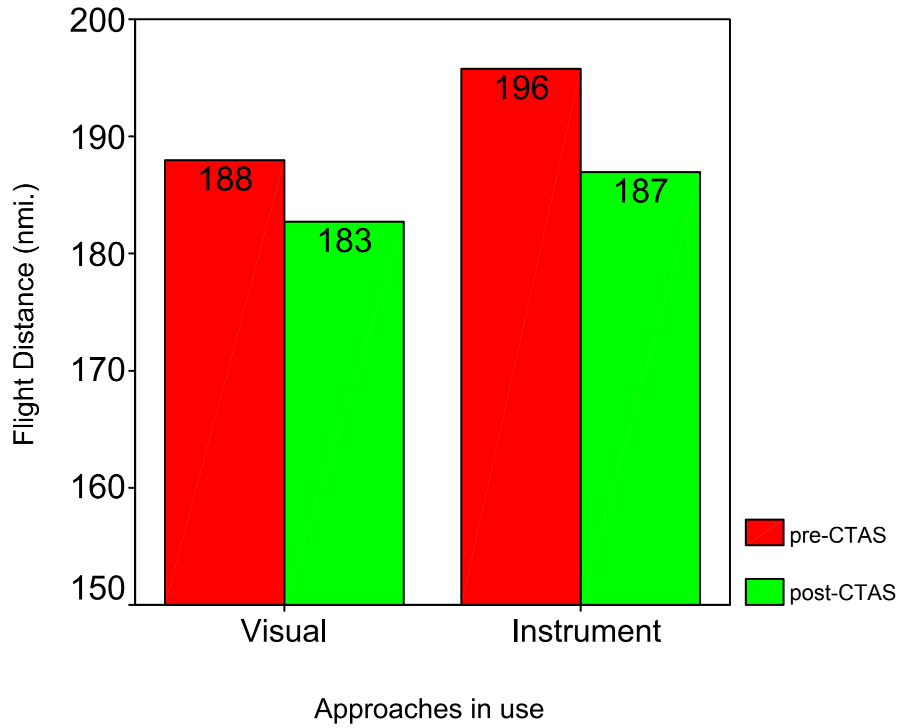


Figure 3-7. MSP Range Rings for Flight Distance Metrics

We first use this data to examine the total efficiency during peak periods, examining flying times and distances from the Center boundary to the runway before and after CTAS implementation. Figure 3-8 demonstrates that the average flight distance between the outer arc and the runway has gone down for both visual and instrument conditions. Note that we start the measurement at the outer arc instead of the extreme arc because aircraft in the extreme arc on the southeast side (see Figure 3-7) are outside the Center boundary. The difference in flight distance is statistically significant at the two percent level, suggesting that there has been a decrease in flying distance.



Mean distance between Outer Arc (OA) and runway for arrivals during peak time periods from October 1999 – October 2001 (no September 2001). Annotation designates mean value.

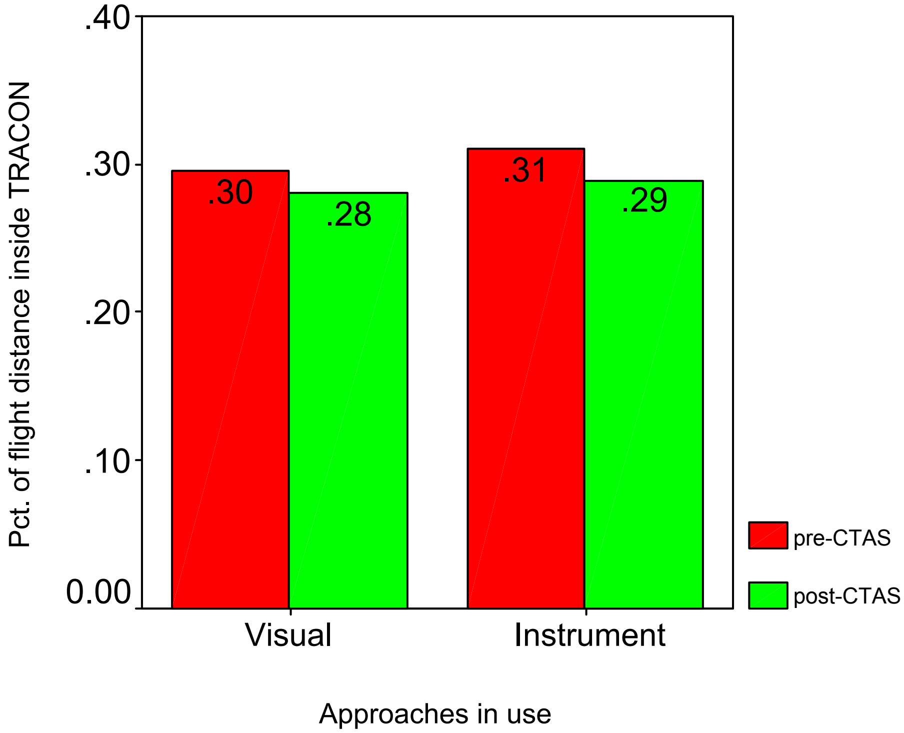
Figure 3-8. Flight Distance between Outer Arc and Runway at MSP

A similar analysis of flight times between the outer arc and the runway revealed no significant change. We feel that flight distance is a more robust measure, however, as it is less sensitive to changes in wind speed and direction.

To study the possible redistribution of delay from lower to higher altitudes, we examine the ratio of time or distance flown inside the TRACON to that from the outer arc to the runway. For this analysis, we use the meter arc (40 nmi) as the approximate TRACON boundary, and include arrival data within the outer arc.

Figure 3-9 displays the distance results for both visual and instrument conditions. The actual straight-line distance from the outer arc to the runway is 160 nmi, and the distance from the meter arc to the runway is 40 nmi; therefore, the nominal fraction of distance inside the TRACON is 0.25. Any fraction above 0.25 represents extra distance needed in the terminal area. Since CTAS implementation, the fraction of distance flown inside the TRACON has decreased for both visual and instrument conditions. This result is statistically significant at the two percent level. The difference in percentages of time within the TRACON was insignificant.

The results of the flying distance metrics at MSP suggest an increase in efficiency for MSP arrivals, and a redistribution of delay from lower, less efficient TRACON airspace to higher altitude Center airspace.



Mean distance between meter arc and runway divided by distance from outer arc to runway during peak times from October 1999 – October 2001 (no September 2001). Annotation designates mean.

Figure 3-9. Percentage of Flight Distance Inside TRACON at MSP

3.3 TMA at ZDV/DEN

3.3.1 Operational Use

TMA started IDU at Denver Center (ZDV) in September 2000 to meter arrivals into Denver International Airport (DEN). The implementation and operation of TMA at ZDV is similar to that at ZMP. See Section **3.2.1** for more specifics on that implementation.

Figure 3-10 demonstrates that the monthly metering times for DEN are much less consistent than those seen at MSP (Figure 3-1). While ZDV metered for a record high 1,378 minutes in June 2001, little metering took place in the following month. (There was no metering in September 2001, but we expect that this is due to the decreased traffic after September 11th.) Although the controllers employ metering at Denver, airport capacity is such that the facility does not require it on a regular basis. The Metrics Team expects that future metering times will increase as demand increases.

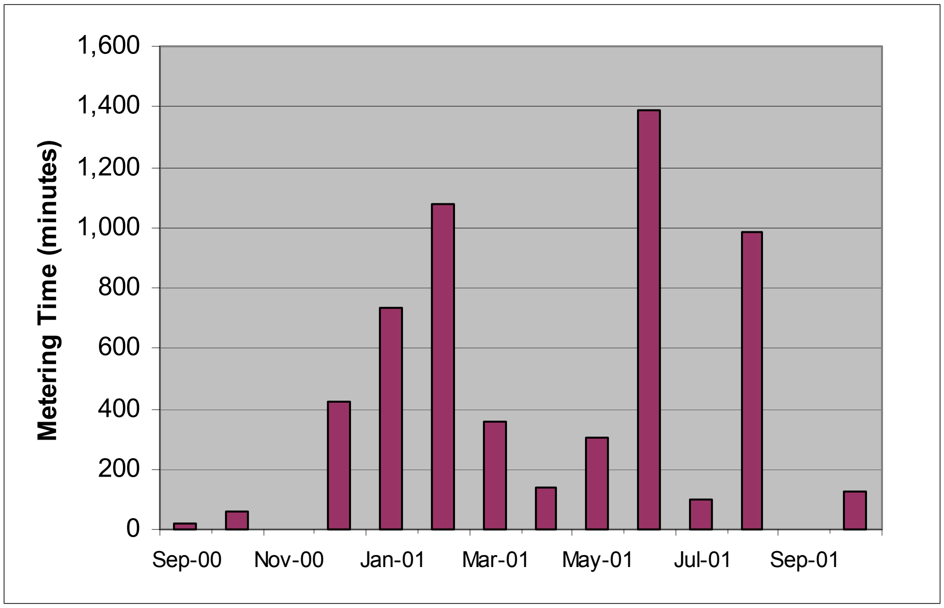
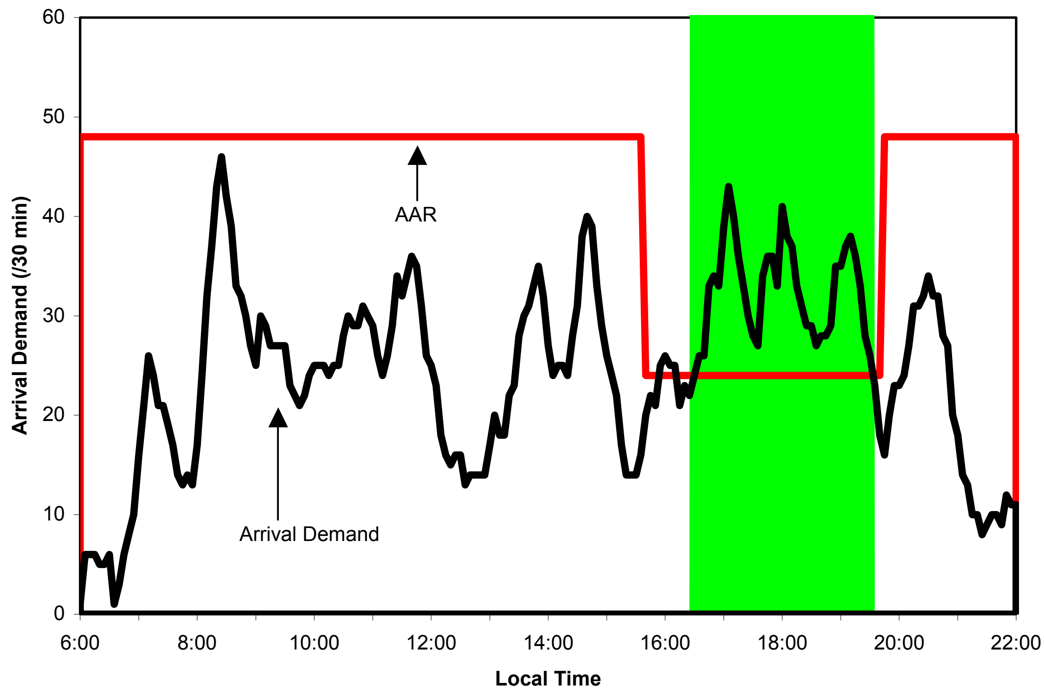


Figure 3-10. ZDV/DEN Total Monthly Metering Times

3.3.2 Metrics Used

The FFP1 metrics for TMA at ZDV/DEN seek to answer the same questions as those asked in Section **3.2.2**. Because arrivals and departures at DEN do not generally share runways, we focus on the arriving aircraft and do not include a section on the operations rate.

While the metrics are nearly identical to those used at MSP, the method for determining peaks is somewhat different. Like MSP, arrivals at DEN tend to occur in regular daily peaks. Unlike MSP, these peaks tend to be shorter in duration and are not as equally spaced, making the analysis by arrival pushes somewhat more difficult. In addition, under most circumstances, the capacity at DEN is much greater than demand, so that metering is not necessary as evidenced by Figure 3-11. Because of these issues, we believe the most accurate way to gauge the effectiveness of TMA is to limit the analysis to those times when the airport is under "stress". In order to determine the stressed periods, we compared arrival demand to the reported AAR. For this analysis, we defined arrival demand to be the maximum of the actual arrival rate (calculated from TRACON data) and the estimated arrival rate (calculated from ETMS actual take-off time plus the filed flight time). Peaks in the actual rate demonstrate stress at the runway, while peaks in the estimated rate quantify the number of flights that wanted to land, thereby revealing stress in the surrounding airspace. Those times for which the arrival demand was greater than the AAR are the stressed periods. For us to include a period for analysis, the duration of the heightened arrival demand had to be longer than 15 minutes. This represents a rather strict measure of stress that should be considered a lower bound on the amount of time the airport is under pressure. Figure 3-11 shows the arrival demand and the AAR at DEN on a day when metering occurred. Shaded sections indicate periods when the arrival demand was greater than the AAR. Since this analysis relies heavily on the AAR, we do not consider times when it was not recorded.



Shading indicates time when arrival demand is greater than AAR.

Figure 3-11. Arrival Demand and AAR at DEN, 23 OCT 2000

We found that arrival demand equals or exceeds capacity less than two percent of the time with the current demand levels at DEN. This agrees with the FAA Airport Capacity Benchmark Study (Reference 7), which states that less than 0.25 percent of flights incur significant delay at DEN. However, total arrival demand has grown 7 percent at DEN since the TMA IDU date, and there is a corresponding increase in the number of stressed time periods. We continue to measure metrics at ZDV/DEN and expect to see impacts of TMA on operations as demand increases.

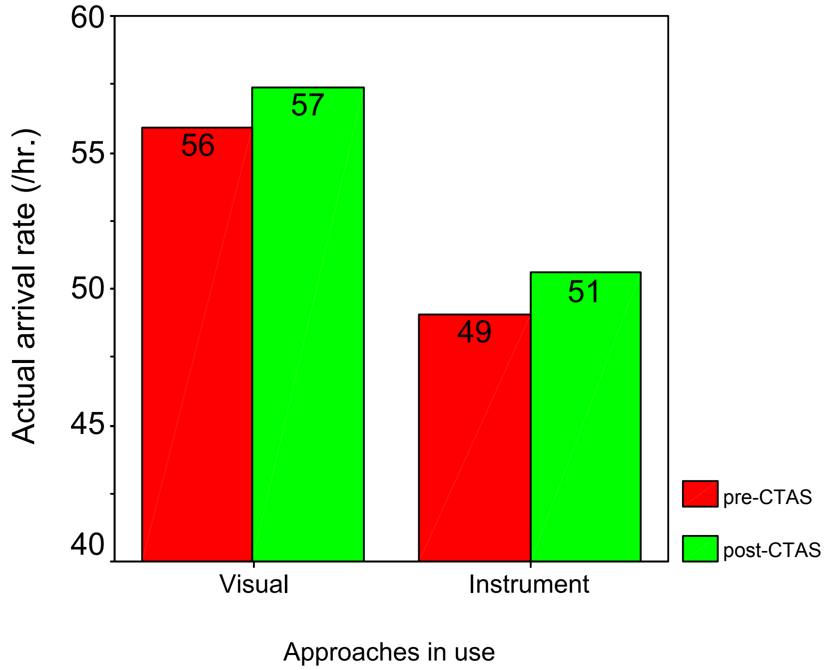
3.3.3 Analysis and Results

3.3.3.1 Airport Acceptance Rate

In April 2001, TRACON managers increased the maximum AAR during optimum conditions at DEN from 108 to 120. Because of this decision, the average AAR increased by approximately five percent. We believe this increase is due to a greater confidence in the operation of automation tools, an increased focus on capacity associated with FFP1, and the FAA Capacity Benchmark Study. Currently, the demand rarely reaches such a rate, but this change in acceptance rates will, in the long term, support increased throughput during stressed periods and reduce delay.

3.3.3.2 Actual Arrival Rate

Although there are only a limited number of stressed time periods, we see a small but statistically significant increase in the mean arrival rate during these times. Figure 3-12 displays the mean actual arrival rate during the stressed periods for different airport conditions. The results have been weighted by the duration of the stressed period (a period of stress that lasts one hour counts four times as much as one that lasts 15 minutes).



Mean actual arrival rate at peak time periods for different airport conditions from September 1999 - October 2001, weighted by peak duration. Annotation designates mean value.

Figure 3-12. DEN Mean Actual Arrival Rate

The graph shows that after the implementation of TMA, the mean arrival rate during times of peak stress increased between one and two planes an hour, depending on whether the airport was operating under visual or instrument conditions. These differences are significant at the five percent level.

3.3.3.3 Flight Times and Distances

The methodology for this analysis is the same as that used at MSP, as detailed in **3.2.3.4**. Figure 3-13 shows the range rings used to calculate the flight time and distance metrics at DEN.

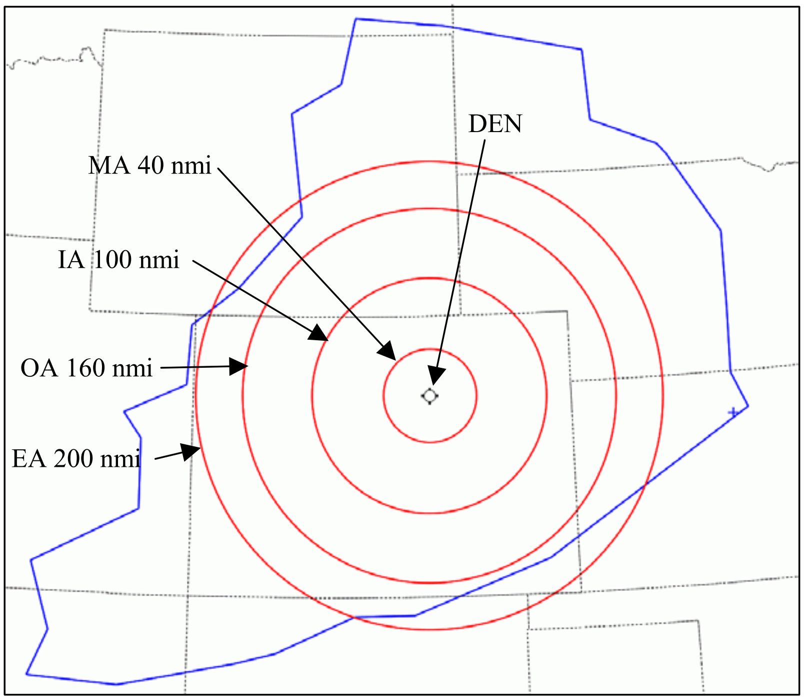


Figure 3-13. DEN Range Rings for Flight Distance Metric

We performed peak period flight time and distance analyses similar to those done at MSP (section 3.2.3.4), and found that while there were decreases in the flight times and distances as well as the redistribution fractions, the results were not significant. We expect that as the demand and number of peak periods increase at DEN, additional data will become available with which to reexamine this issue.

3.4 TMA at ZLA/LAX and CTAS-Terminal at SCT/LAX

3.4.1 Operational Use

3.4.1.1 CTAS-Terminal

As the installation and adaptation of pFAST progressed at SCT, it became apparent that operations were different from those for which pFAST was designed, and significant changes to the program code would have to be made in order for the original implementation to work effectively. However, the facility personnel determined that they could achieve improvements in situational awareness without the tool providing suggested runway assignments and sequence numbers. This interim implementation uses auxiliary displays to provide controllers at key positions with a broader view, encompassing traffic from outside the TRACON airspace all the way to the runway. Because the implementation at SCT differs greatly from the original product tested at DFW, and to avoid confusion, the Free Flight Program Office now refers to this capability as CTAS-Terminal. Initial Daily Use (IDU) of CTAS-Terminal started in February 2001, and Planned Capability Available (PCA) status was achieved in August 2001.

As originally designed, pFAST supplies suggested runway assignments and sequence numbers for arrival aircraft to the controllers. It also has plan view (P-GUI) and timeline view (T-GUI) displays that are normally installed in the Traffic Management Unit for planning purposes. Because CTAS-Terminal gets information from the ARTCC long-range radar, as well as the TRACON short-range radar, these supplemental displays can convey the "big picture" of the traffic situation better than other traditional displays. Further, these displays show the current data block information regardless of which sector controller may be entering or updating the data. At SCT, this additional information is given to the two LAX final controller positions and the two primary LAX feeder sectors, through additional displays installed at those operating positions.

3.4.1.2 TMA

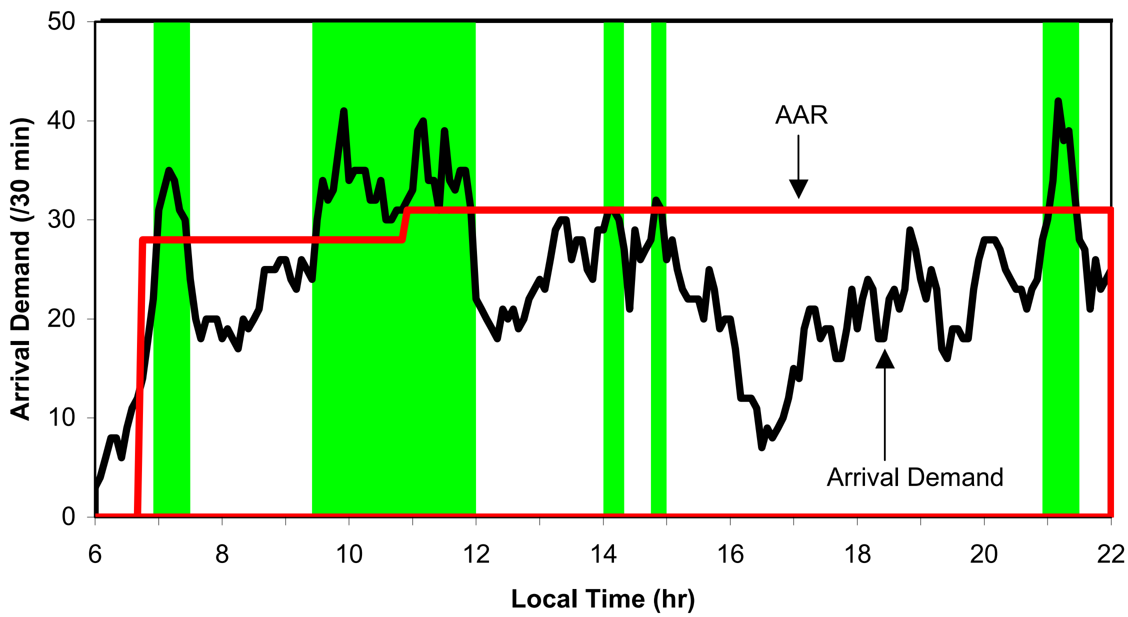
TMA started IDU at ZLA for LAX in June 2001. The ZLA implementation of TMA is somewhat different from that described for ZMP and ZDV (Section **3.1.1**). Currently, TMA is primarily a strategic tool used by ZLA traffic managers to determine the necessity of location-based miles-in-trail (MIT) restrictions. The overlay list that allows tactical use of the tool by individual controllers is not in use at ZLA because the Center does not currently use time-based metering. ZLA hopes to employ time-based metering within the next year, at which time tactical use of TMA will begin.

The TMU also indicated a mechanism by which TMA decreases the amount of gate delay for internal departures. Traffic into LAX is dominated by large flows coming from airports external to ZLA. Traffic to LAX from airports within the Center must wait for gaps in this flow in order to get clearance to depart. This frequently causes long ground delays for aircraft trying to fly to LAX from these local airports. TMA allows the TMU to accurately determine the duration of gaps in the flow and grant more clearances for these internal departures.

3.4.2 Metrics Used

Metrics employed to measure the effectiveness of both TMA and CTAS-Terminal are similar to those described in section **3.1.2**. It is difficult to differentiate between changes in the arrival rate due to the tools separately; consequently, we attribute rate changes to the combined effect of the CTAS system. Because arrivals and departures at LAX do not generally share runways, we focus on arriving aircraft and do not include a section on operations rate. The flight time and flight distance metrics between rings at LAX have also been dropped in favor of a more detailed analysis of circular holding. The reason for this change was two-fold: the complexity of SCT airspace made measurement between rings difficult, and the new algorithm provides a metric that allows us to examine the effect of CTAS-Terminal on holding within TRACON airspace. We also include a measure of departure delay at airports controlled by the Center as an indication of the tactical benefit of TMA at ZLA.

Unlike some of the other CTAS sites (MSP, DFW, DEN,), LAX is not a major hub, and therefore does not have clearly defined peaks that occur each day. (Compare the sample arrival rate graph in Figure 3-14 with the arrival traffic at MSP shown in Figure 3-2). As mentioned in the previous section, operators anticipate the most benefit from situational awareness provided by CTAS-Terminal during periods when the airport is under "stress." In order to determine the stressed periods, we compared arrival demand to the reported AAR, as explained in detail in Section **3.2.2**. Figure 3-14 shows arrival demand and the AAR. Shaded sections indicate periods when the arrival demand was greater than the AAR. Since this analysis relies heavily on the AAR, we do not consider times when the AAR was not recorded (e.g. the time before 6:45 am in Figure 3-14.)



Shaded areas indicate arrival demand greater than AAR.

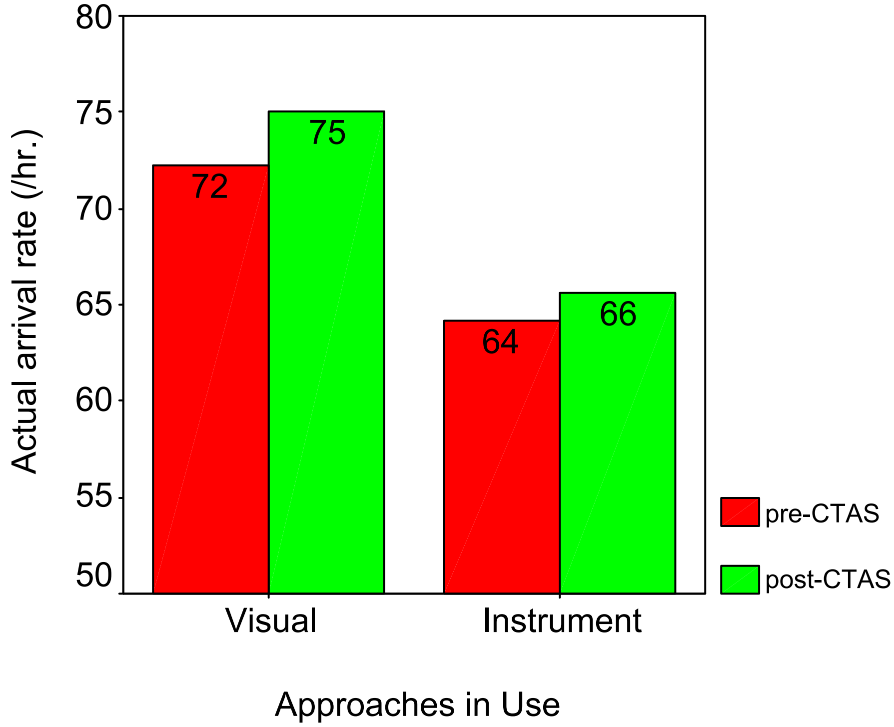
Figure 3-14. Arrival Demand and AAR at LAX, 26 FEB 2001

For most of the following analyses the data set includes information from February 2000 through 31 October 2001. CTAS-Terminal became operational in February 2001.

3.4.3 Analysis and Results

3.4.3.1 Actual Arrival Rate

For each peak period identified by the method described in Section **3.2.2,** we calculate an hourly arrival rate. Figure 3-15 presents the mean peak arrival rates before and after CTAS implementation for both visual and instrument approaches. This simple comparison suggests that peak arrival rates are higher since CTAS implementation. As expected, the rates are lower for instrument conditions.



Mean actual arrival rate at peak time periods for different airport conditions from February 2000 - October 2001, weighted by peak duration. Annotation designates mean value.

Figure 3-15. LAX Mean Actual Arrival Rate

To support this result we also performed a regression on the arrival rate, in which we included several variables relating to airport conditions, weather, and fleet mix. Table 3-1 displays the results of the regression. The overall regression is statistically significant, as suggested by the large value of the F statistic, but the goodness-of-fit (Adjusted R^2 statistic) only accounts for approximately 53 percent of the variation. The coefficients of the model (defined in Table 3-1) all have the expected signs. The percentage of heavy aircraft, instrument approaches, rain, wind gust speed, and the airport being in an East configuration (requiring aircraft to land from the ocean side) all have negative effects on the arrival rate. The arrival rate increases due to increases in the visibility, ceiling, or the inboard usage (inner runways used for both arrivals and departures). The CTAS variable has a positive coefficient of 1.669 suggesting that the CTAS tools help to increase the arrival rate between one and two airplanes an hour during peak arrival periods.

Table 3-1. Actual Arrival Rate Regression Results

	R Square	Adusted R Square	F	Sig.
	.531	.530	305.789	.00000

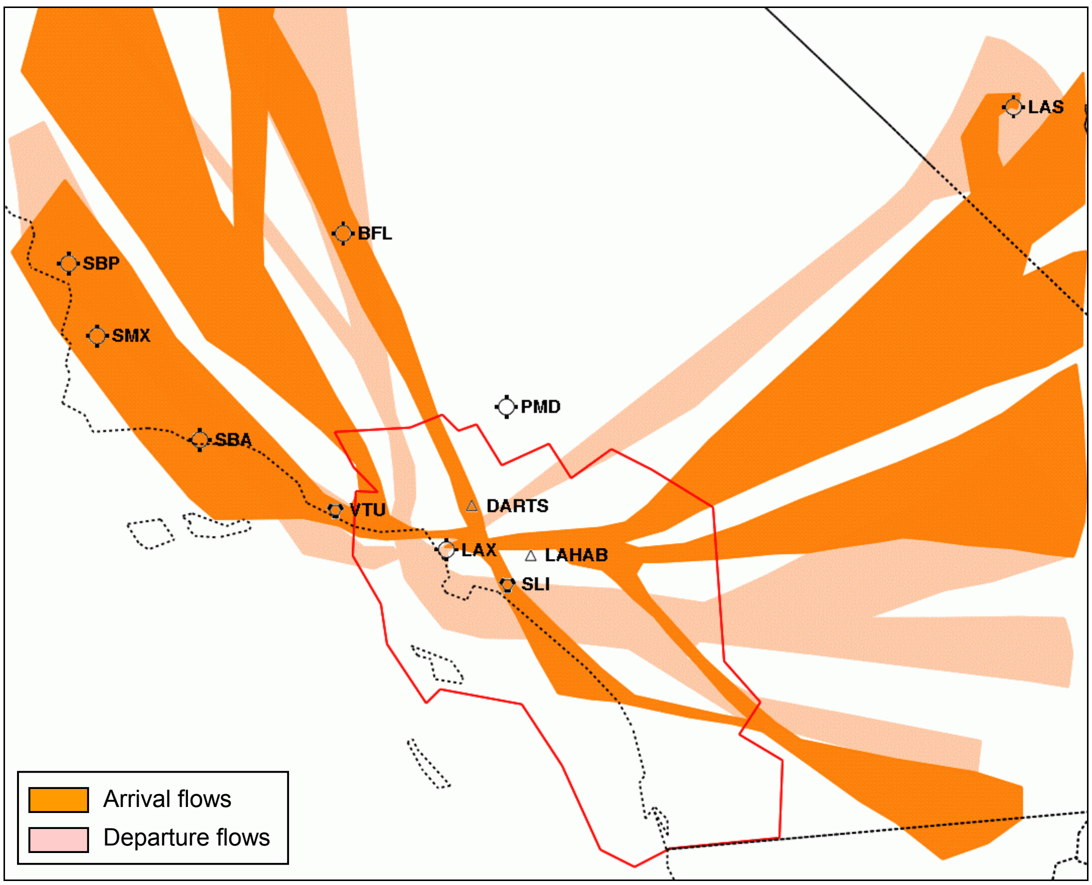
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	65.352	.562		116.321	.000
Inst. Approach	-2.173	.330	-.114	-6.593	.000
CTAS	1.669	.288	.087	5.793	.000
East configuration	-4.608	.612	-.113	-7.531	.000
Pct. heavy aircraft	-11.497	2.078	-.078	-5.532	.000
Rain	-3.578	.633	-.085	-5.655	.000
Inboard usage	9.591	.368	.430	26.069	.000
Gust speed	-.185	.049	-.055	-3.767	.000
Visibilty	.288	.045	.096	6.421	.000
Ceiling	1.476E-04	.000	.232	13.745	.000

	Explanation of Variables
Inst. Approach	0 = Visual approaches, 1 = Instrument approaches
CTAS	0 = pre-CTAS, 1 = post CTAS
East configuration	0 = West airport configuration, 1 = East or Ocean configuration
Pct. heavy aircraft	Percentage of total aircraft during peak which are heavy
Rain	0 = no rain in surface weather report, 1 = rain in report
Inboard usage	0 = Inboards not in use, 1 = Inboards in use
Gust speed	Surface gust velocity in knots
Visibilty	Surface visibility in statute miles
Ceiling	Ceiling in feet with unlimited ceiling replaced with 35,000 ft.

3.4.3.2 Holding near LAX

Because of the airspace complexity around LAX, we decided that the range ring methodology used in previous analyses was too crude to properly measure delay distribution in the system. Instead, we developed a more microscopic algorithm to quantify the amount of holding in SCT airspace for LAX arrivals. Controllers and management who handle LAX traffic maintain that the implementation of CTAS-Terminal at SCT and TMA at ZLA has decreased holding.

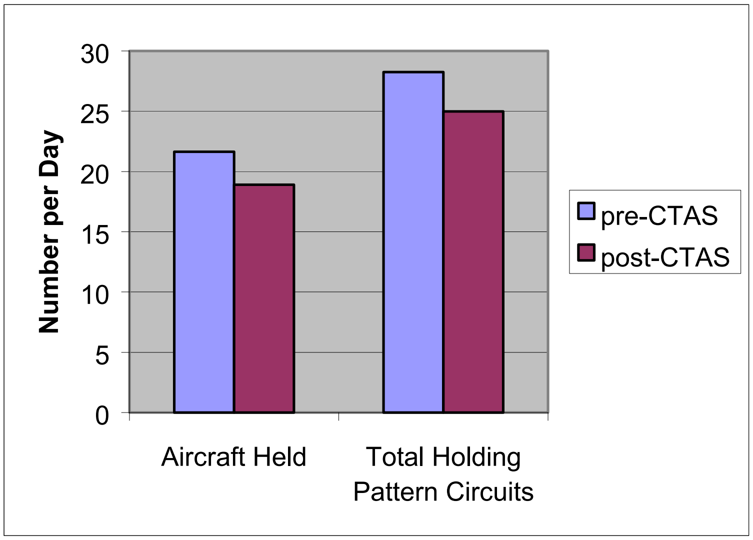
To compute the number of aircraft held, and the number of holding circuits per aircraft held, we examined ARTS track data for LAX arrivals. Our algorithm calculates the number of times an aircraft completes a 360-degree change of direction (rounding up if the last loop is more than 270 degrees) while remaining within 20 nautical miles of two fixes and two NAVAIDS suggested by facility traffic managers (see Figure 3-17). Unfortunately, there are large gaps in our track data so the analysis was limited to the summer months (June, July, and August) of 2000 and 2001. In February 2001, CTAS-Terminal was implemented at SCT, and in June 2001 TMA became operable at ZLA. Therefore, our analysis examines the effect of both CTAS systems together and not separately. The data from both the spring of 2000 and 2001 was not reliable enough to isolate separate effects of the two different CTAS tools.



Annotations show fixes (DARTS and LAHAB) and NAVAIDS (SLI and VTU) used in the holding study and most of the local airports used in the delay study.

Figure 3-17. Arrival and Departure Flows Into LAX

Figure 3-18 presents the results of this analysis. The results indicate that the number of planes that were held and the total number of holding pattern circuits both decreased after CTAS implementation. The number of planes held dropped by about 13 percent while the number of holding circuits per day dropped by about 12 percent.



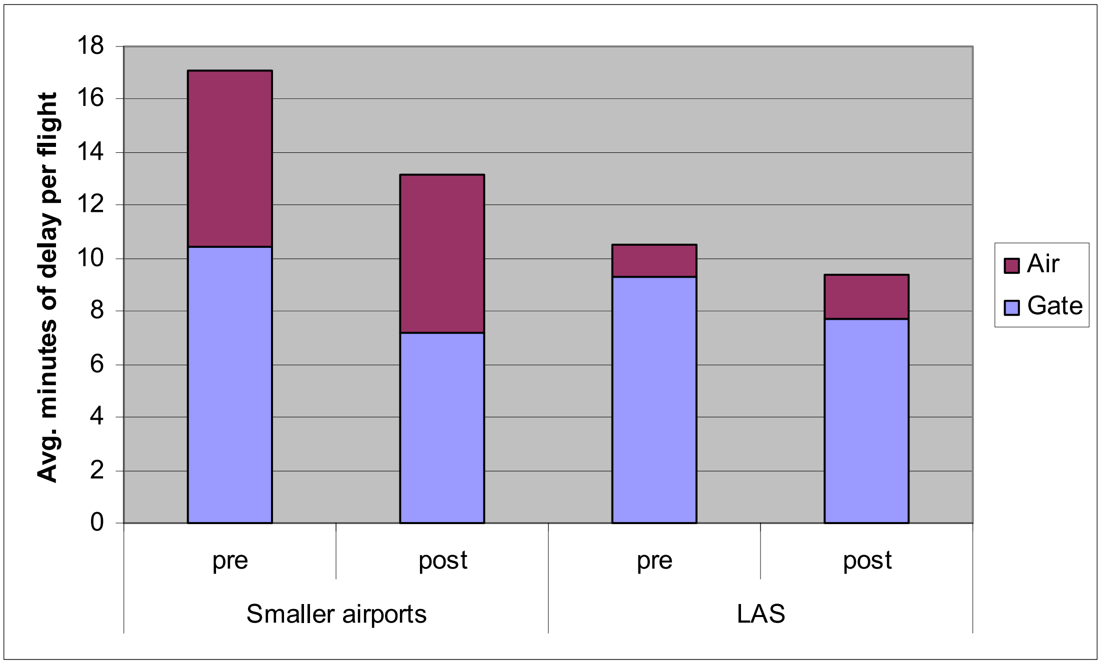
Pre-CTAS data from June-August of 2000, post-CTAS from June-August 2001.

Figure 3-18. Holding Near LAX

3.4.3.3 Delay for ZLA Internal Departures

Delay is subject to changes in demand and weather that are independent of ATC performance. For this reason, we generally focus on operational throughput measures to gauge the impact of FFP1 tools. However, in the case of ZLA internal departures to LAX, delay seems to be the most applicable metric. Traffic in LAX is dominated by large cross-country flows, so that flights originating at airports close to LAX are often difficult to fit into the stream. One can see how these difficulties may arise by looking at Figure 3-17, which shows the location of some of the local airports and their positions relative to the major inbound flows for LAX. As a result, these flights are often held at the departure airport, waiting for an available opening in the LAX arrival stream before being released for departure by ZLA. Anecdotally, gate delays in excess of an hour were not uncommon. The implementation of TMA at ZLA could help facilitate the meshing of internal departures with the LAX arrival streams, thereby reducing delay for the local flights.

To assess the impact of CTAS on internal departures, we compiled data on delay associated with these flights from the Aviation System Performance Metrics (ASPM) database. We looked at both gate delay (at the departure airport) and air delay, choosing not to consider taxi-in or taxi-out delays, since they did not seem relevant to the usage of CTAS. We calculated average delay per flight for the airports that require a release by ZLA for departures to LAX; these airports include Fresno, San Luis Obispo, Las Vegas, Monterey, Bakersfield, Palmdale, Santa Maria, and Santa Barbara. We compared averages for pre-CTAS (historical average from Sept. 1999 through May 2001) to post-CTAS (average over June through August, 2001).



Source: ASPM. Pre-CTAS data from September 1999 – May 2001, post-CTAS data from June 2001 – August 2001.

Figure 3-19. Delay for ZLA Internal Departures to LAX

The comparison of delay for pre- and post-CTAS can be seen in Figure 3-19. We have shown Las Vegas (LAS), the only major airport in the ZLA-released category, separately from the other, smaller airports. There has been a substantial reduction in gate delay associated with the implementation of CTAS. For smaller airports, gate delay was reduced by 31 percent, while for LAS gate delay was down by 17 percent. Airborne delay was also down by 10 percent for the smaller airports, so that the total of airborne plus gate delay was reduced by 23 percent for those airports. For LAS, the reduction in gate delay was somewhat offset by an increase in airborne delay, but overall the total of airborne plus gate delay was down by 10 percent.

3.5 TMA at ZTL/ATL and ZMA/MIA

There are four locations at which TMA has been installed but the facilities have not implemented time-based metering. We have already discussed the benefits of TMA for one of these locations (i.e., ZLA). The other three TMA locations that are not using time-based metering are Atlanta ARTCC for Atlanta Hartsfield International arrivals, Miami ARTCC for Miami International arrivals, and Oakland ARTCC for San Francisco International arrivals. While we have not yet been able to statistically quantify benefits for these locations, we do have some anecdotal evidence of use of the tool by traffic managers.

The Traffic Management Coordinator (TMC) assigned to Atlanta TRACON and Atlanta

ARTCC made the following observations in an e-mail message received on November 2, 2001:

> TMA feed is better than ASP. Since we operate TMA in UR [unrestricted rate] mode, we have found that it delivers a rate more closely matching what A80/ATL can actually land. While shadowing two weeks ago ATL was advertising visual approaches and a 92 [airport acceptance] rate. The TMC had called 10 MIT to the north 2 arrival fixes and 20 MIT to the south 2 arrival fixes based on this delay data. I advised the TMC that TMA was forecasting a performance rate of about 104 and called for no delays. He removed the MIT restrictions so we could verify TMA. After the [arrival] push, ARMT [an internal analysis tool] data showed A80/ATL performed in excess of a 102 rate. A80 never got pushed out of their normal 20 mile final and a base/downwind feed.

The following Air Traffic Control System Command Center (ATCSCC) log entry from December 10, 2001 also refers to TMA use at Atlanta Center:

> …ZTL used TMA for the ATL arrival push. ATL called the AAR 78, but ZTL used an AAR of 70 based on TMA data to determine the ATL MIT. ZTL advised that the TMA generated AAR was in fact more accurate than the official 78 rate. ZTL was pleased that the push [was] managed very well.

At the Miami ARTCC, a Traffic Management Coordinator reported the following:

> CTAS is extremely helpful when I try to implement miles-in-trail, by assisting me with different scenarios, i.e. free flowing one particular meter-fix.

These messages suggest that ZTL and Atlanta TRACON are using TMA to better determine the appropriate acceptance rates for ATL, and that ZMA is using the tool to better match the specified AAR. We expect that with further data collection and analysis, we will be able to demonstrate that arriving aircraft are experiencing less delay since the implementation of TMA at these facilities.

4.0 REFERENCES

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6. Swenson, H.N., et al, "Design and Operational Evaluation of the Traffic Management Advisor at the Fort Worth Air Route Traffic Control Center," 1st USA/Europe Air Traffic Management Research and Development Seminar, Saclay, France, June 1997.

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5.0 ACRONYMS

AAR	Airport Acceptance Rates
ANOVA	Analysis of Variance
ARTCC	Air Route Traffic Control Center
ASP	Arrival Sequencing Program
ASPM	Aviation System Performance Metrics
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATL	Atlanta Hartsfield International Airport
CAASD	Center for Advanced Aviation System Development
CCLD	Core Capability Limited Deployment
CHI	Computer Human Interface
CNAC	Center for Naval Analysis Corporation
CODAS	Consolidated Operations and Delay Analysis System
CTAS	Center TRACON Automation System
DEN	Denver International Airport
DFW	Dallas/Ft. Worth International Airport
DR	Discrepancy Report
EDCT	Estimated Departure Clearance Time
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FDIO	Flight Data Input/Output
FFP1	Free Flight Phase 1
FFPO	Free Flight Program Office
FL	Flight Level
FSM	Flight Schedule Monitor
GAL	Gallon
GDP	Gross Domestic Product
GDP	Ground Delay Program
GDP-E	Ground Delay Program Enhancements
GMT	Greenwich Mean Time
GPD	Graphic Plan Display
HCS	Host Computer System
IDU	Initial Daily Use
IFR	Instrument Flight Rules
LAS	Las Vegas McCarran International Airport
LAX	Los Angeles International Airport
LB	Pound
LOA	Letters of Agreement
MIA	Miami International Airport

MIT	Miles-in-Trail
MOU	Memorandum of Understanding
MSP	Minneapolis/St. Paul
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Control Association
NEXTOR	National Center of Excellence for Aviation Operational Research
nmi	Nautical mile
NRP	North American Route Program
NWA	Northwest Airlines
OAG	Official Airline Guide
OD	Operational Deviation
OE	Operational Error
PCA	Planned Capability Available
pFAST	Passive Final Approach Spacing Tool
P-GUI	Planview Graphical User Interface
RAC	Radar Associate Controller
RPM	Revenue Passenger Miles
SCT	Southern California TRACON
SLI	Seal Beach Airport
SMA	Surface Movement Advisor
SOP	Standard Operating Procedures
SUA	Special Use Airspace
T-GUI	Timeline Graphical User Interface
TMA	Traffic Management Advisor
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control Facility
URET	User Request Evaluation Tool
VFR	Visual Flight Rules
VTU	Ventura Airport
WAFDOF	Wrong Altitude For Direction Of Flight
ZDV	Denver Center
ZFW	Ft. Worth Center
ZID	Indianapolis Center
ZKC	Kansas City Center
ZMA	Miami Center
ZME	Memphis Center
ZMP	Minneapolis Center
ZTL	Atlanta Center